Radiological Health Data and Reports

VOLUME 9, NUMBER 11
NOVEMBER 1968
(Pages 619-704)

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service

INTERNATIONAL NUMERICAL MULTIPLE AND SUBMULTIPLE PREFIXES

Multiples and submultiples	Prefixes	Symbols	Pronunciations
10^{12}	tera	T	tĕr' a
10^{9}	giga	G	jĭ' ga
10^{6}	mega	M	mĕg' a
10^{3}	kilo	k	kĭl' o
10^{2}	hecto	h	hĕk' to
10	deka	da	dăk' a
10^{-1}	deci	d	dĕs' i
10^{-2}	centi	c	sĕn' ti
10^{-3}	milli	m	mĭl' i
10^{-6}	micro	μ	mi' kro
10^{-9}	nano	n	năn' o
10^{-12}	pico	p	pē' co
10^{-15}	femto	f	fĕm' to

SYMBOLS, UNITS, AND EQUIVALENTS

Symbol	Unit	Equivalent
BeV	billion electron volts	GeV
Ci	curie	3.7×10^{10} dps
cm	centimeter(s)	0.394 inch
cpm	counts per minute	
dpm	disintegrations per minute	
dps	disintegrations per second	
eV	electron volt	1.6×10^{-12} ergs
g	gram(s)	
GeV	giga electron volts	1.6×10^{-3} ergs
kg	kilogram(s)	1,000 g=2.205 lb
km^2	square kilometer(s)	
kVp	kilovolt peak	
m^3	cubic meter(s)	
mA	milliampere(s)	
mCi/mi^2	millicuries per square mile	0.386 nCi/m^2 (mCi/km^2)
MeV	million (mega) electron volts	1.6×10^{-6} ergs
mg	milligram(s)	
mi^2	square mile(s)	
ml	milliliter(s)	
mm	millimeter(s)	
nCi/m^2	nanocuries per square meter	2.59 mCi/mi^2
pCi	picocurie(s)	10^{-12} curie=2.22 dpm
R	roentgen	
rad	unit of absorbed radiation dose	100 ergs/g

RADIOLOGICAL HEALTH DATA AND REPORTS

Volume 9, Number 11, November 1968

In August 1959, the President directed the Secretary of Health, Education, and Welfare, to intensify Departmental activities in the field of radiological health. The Department was assigned responsibility within the Executive Branch for the collation, analysis, and interpretation of data on environmental radiation levels such as natural background, radiography, medical and industrial uses of isotopes and X rays, and fallout. The Department delegated this responsibility to the National Center for Radiological Health, Public Health Service.

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Reports

Whole Body Cesium-137 and its Relation to Body Composition and Diet

R. C. Steinkamp, T. W. Sargent, E. Isaacs, N. L. Cohen, E. M. Hutson, and *N. D. Kunkel*[1]

Between September 1962 and July 1963, a time of rising cesium–137 content in the biosphere, whole body cesium–137 and potassium–40 measurements were performed in an Argonne-type scintillation counter on 80 subjects; 52 men and 28 women. These data have been correlated with body composition estimates of body fat and lean body mass. Seventy-eight of the subjects had diet interviews. The intakes of food categories were correlated with *in vivo* cesium–137 measurements. The results suggest that calculations of dose rates for cesium–137 may be more meaningful if based on lean body mass rather than total body weight, as is done presently.

Intakes of milk and fruits and vegetables correlated significantly with *in vivo* cesium–137 measurements for those subjects with extremely low or extremely high food intakes. A regression equation was determined to calculate pCi cesium–137/g potassium in people from pCi cesium–137/g potassium in milk. There appeared to be a time lag of 4 to 5 months between rising values of cesium–137 in milk and those in people, consistent with the biological half-life of cesium–137.

Since the first detection of cesium–137 in human subjects in 1956, this long-lived nuclear fission product has received considerable attention (*1*). The contribution of cesium–137 to the total body burden of radioactivity, the mechanisms of entry into the biosphere, and the metabolic fate in men and experimental animals have been studied since 1956.

Cesium–137 has been assumed to be distributed uniformly throughout the body for dose-rate calculations in man (*2, 3*). The present study, performed during a time of increasing cesium–137 body burdens, presents cesium–137 measurements in relation to body composition and potassium measurements as well as food intake. Ingestion of either low or high amounts of milk as well as of fruits and vegetables have been related to cesium–137 body burdens.

Materials and methods

A detailed description of the subjects and methods has been published previously (*4*). The subjects of this study were 80 healthy San Francisco Bay Area residents between the ages of 25 and 44 years. Fifty-two men (49 Caucasian and 3 Negro) and 28 Caucasian women were studied between September 1962 and July 1963.

Cesium–137 and potassium were measured in an Argonne-type whole body scintillation counter (*5*). Suitable precautions were used to avoid external contamination. The mean counting efficiency for cesium–137 was 8.1 counts per minute (cpm) per nCi in a 180 keV band at the photopeak, with a standard

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deviation of 0.96 cpm/nCi (*6*). For potassium, an average counting efficiency of 1.09 ± 0.10 cpm/g potassium in a 300 keV band at the photopeak, with a standard deviation of 9.7 percent was determined by calibration with potassium–42 injected into normal volunteers.

The dose rate for cesium–137 was calculated by using the formula (*3*):

$$D = 11 \frac{\text{cesium–137 in nCi}}{\text{body weight in kg}} \text{ mrem/year},$$

where 11 is the dose conversion factor based on the absorption of 0.59 MeV per disintegration.

Body fat was estimated for each subject from four anthropometric measurements according to a linear regression equation appropriate for his age, race and sex (*7*). Lean body mass was calculated by subtracting estimated body fat in kilograms from the subject's total body weight in kilograms.

Twenty-four hour diet recall records were obtained for all subjects except two of the men who were measured for radioactivity in January and February 1963. Methods for diet recall (*4*) and results of nutrient calculation (*9*) have been previously reported. For this report, the diet interviews were reevaluated to obtain quantities consumed for five food categories. These were milk, milk plus all other dairy products calculated in milk equivalents[2], cereals, animal protein foods (including lean meats of all types, fish and eggs), and fruits and vegetables. All food categories were calculated in ounces consumed except for the cereals group, which was scored in number of servings[3].

Body composition and total body cesium–137

Table 1 presents means and standard deviations for body composition, cesium–137 measurements and total body potassium. Mean percent body weight as fat estimated from the anthropometric measurements compares favorably with that calculated from total body water and body density measurements (*4, 7, 9*) for a larger group of subjects (table 2). Estimates of lean body mass by anthropometric methods compare favorably with those obtained by the laboratory procedures.

Table 1. Average body composition cesium–137 and potassium values for adults 25 to 44 years old

Parameter measured	Men (n = 52)		Women (n = 28)	
	Mean	S.D.	Mean	S.D.
Body weight (kilograms)	77.97	12.37	62.17	13.33
Lean body mass (kilograms)	58.61	7.93	41.44	7.44
Body weight as fat (percent)	24.3	6.38	32.8	5.08
Cesium-137 (nCi)	7.4	2.25	5.3	2.17
Potassium (grams)	137	16.7	91	8.25
Cesium-137/potassium (pCi/g K)	53.9	12.9	57.8	20.0
Dose rate of cesium-137 (mrem/yr)	1.06	0.35	0.96	0.39

Table 2. Percent body weight as fat for adults 25 to 44 years old

Category of subjects	Number of subjects	Mean percent body weight as fat
Caucasian men, 25-34 yrs	35	22.0
Caucasian men, 35-44 yrs	34	26.8
Caucasian women, 25-34 yrs	33	30.7
Caucasian women, 35-44 yrs	31	35.8
Negro men, 25-44 yrs	34	22.5

On the basis of determinations of 311 people from 30 States, Anderson calculated total potassium values of 139 grams (standard deviation = 19 percent) for a "standard" man weighing 70 kg (*10*). Our determinations yield a value of 123 grams potassium for a 70 kg man.

Mean cesium–137/potassium ratios were slightly greater and total dose rates were slightly lower for women than for men, reflecting the lower levels of potassium, lean body mass, and total body weight for women. Mean values of cesium–137/potassium for people in the United States were reported as 69 pCi/g for fiscal year 1959, and 28 pCi/g for the first quarter of 1962 by the Walter Reed Institute of Pathology (*11*). In England, Rundo and Newton (*12*) found values ranging from 50 to 90 pCi cesium–137/g of potassium and average total cesium–137 values of 7.0 to 12.6 nCi between October 1962 and July 1963 (comparable to the time period and the results of the present study).

[2] Milk equivalents were taken from *Conversion Factors and Weights and Measures for Agricultural Commodities and Their Products.* Production and Marketing Administration of the U.S. Department of Agriculture, May 1952, and are: 1 ounce hard cheese = 10 oz. milk; 1 ounce cottage cheese = 6 oz. milk; ½ cup ice cream = 8 oz. milk.

[3] Each of the following was considered as one serving of cereal: 1 slice bread; ½ cup cereal, either cooked or dry; 2 cookies; 3 ounces cake.

Table 3 presents correlation coefficients, "r" for cesium–137 content with estimated body composition and potassium measurements for all subjects by sex based on the consideration of variables from a bivariate normal distribution. Total cesium–137 values were significantly correlated with potassium measurements for both men and women. It is interesting that for the women, correlation of cesium–137 with lean body mass was greater than with total body weight, as was the case for men.

Table 3. Correlation of cesium–137 content (nCi) with estimated body composition and potassium measurements—all subjects

Parameter measured	Men (n = 52)		Women (n = 28)	
	r value	P	r value	P
Body weight (kilograms)	0.324	<0.02	0.082	NS
Lean body mass (kilograms)	.498	<.01	.221	NS
Body weight as fat (percent)	−.211	NS	−.264	NS
Potassium (grams)	.646	<.01	.509	<0.01

NS, not significant.

Studies of mammalian tissues indicate that fat has the lowest cesium–137 concentration of any tissue studied. In dogs chronically exposed to cesium–137, Furchner and colleagues (*13*) found the ratio of cesium–137 in fat to cesium–137 in whole body was < 0.01 while the ratio cesium–137 in muscle to cesium–137 in whole body was >2.0. Concentrations in other soft tissues, except the gonads, pelt and fat approximated whole body cesium–137 concentration. The low concentrations in the gonads and pelt were related to the large amount of fat and low concentration of muscle in these organs. More recently, Baratta and Ferri (*14*) have found in human autopsy specimens that the greatest concentrations of cesium–137 was in muscle, and was about twice that in spleen and liver. Unfortunately, no data were presented for fat specimen analyses in their study.

The suggestion of Langham and Anderson (*15*) to express the concentration of cesium–137 in the body in terms of cesium–137/potassium ratio, because of the chemical similarities of cesium to potassium, has been generally accepted. Rundo (*16*), however, has pointed out differences as well as similarities between cesium and potassium metabolism in man. Whole body cesium retention has been found by Rundo (*16*) and Grundy and Sargent (*6*) to be a two-component exponential function of time. Approximately 10 percent of ingested cesium is excreted with a half-life of 1 to 2 days; the major part is excreted with a half-life of about 110 days. Rundo has attributed a larger part of the variability of cesium–137 contents among individuals to the variability in biological half-life and at the same time has recognized that dietary habits must control the cesium–137 level reached in the body.

Although atmospheric testing was resumed in September 1961, a rise in cesium–137 values has been noted only since the summer of 1962 (*17*). Since the time period during which our subjects were measured encompassed the rising trend in cesium–137 values, it is unlikely the cesium–137 body burdens of the subjects were in equilibrium with their diets. The cesium–137/potassium ratios, therefore, have been averaged by quarter years in table 4. Analysis of variance among the quarter years provided F values of 6.20 for men and 21.4 for women. The critical F values at the 1 percent level are 4.22 and 4.72, respectively.

Because of the increase of cesium–137 body burden over time and the few subjects measured during the first and last months of the study, further analysis of cesium–137 and body composition was limited to those measured between October 1962 and June 1963. There

Table 4. Cesium–137/potassium ratios for men and women living in the San Francisco Bay area by quarter year

Period	Men (cesium-137/potassium ratio, pCi/g)					Women (cesium-137/potassium ratio, pCi/g)				
	Number of subjects	Mean	S.E. of mean	Minimum	Maximum	Number of subjects	Mean	S.E. of mean	Minimum	Maximum
September 1962	4	55.80	5.62	36.52	67.43	—	—	—	—	—
October-December 1962	23	47.26	2.34	24.91	85.67	8	46.66	3.89	27.44	55.38
January-March 1963	16	56.54	2.81	43.88	87.70	9	50.37	3.67	42.86	57.56
April-June 1963	9	65.54	3.75	56.99	82.27	8	60.01	3.89	45.32	77.12
July 1963	—	—	—	—	—	3	103.77	6.31	75.11	128.80

were totals of 31, 25 and 17 subjects measured in the three quarter years. Total body cesium–137 measurements were 5.79 ± 1.80[4] nCi for October to December 1962, 6.69 ± 2.41 nCi for January to March 1963, and 7.57 ± 2.77 nCi for April to June 1963. Table 5 presents the correlation coefficients for these data with total body weight, lean body mass and potassium. As the cesium–137 contents increased with time, correlations with body composition measurements became greater. There was little difference among the groups for mean total body weight and for mean lean body mass.

Table 5. Correlation coefficients for cesium–137 measurements and for body composition by quarter year

Parameter measured	Oct-Dec 1962 (n=31)	Jan-Mar 1963 (n=25)	April-June 1963 (n=17)
Cesium-137 (nCi) and body weight (kilograms)	0.369 *	0.572	0.713
Cesium-137 (nCi) and lean body mass (kilograms)	.583	.768	.842
Cesium-137 (nCi) and potassium (grams)	.670	.866	.914
Body weight (kilograms) and potassium (grams)	.710	.723	.791
Lean body mass (kilograms) and potassium (grams)	.868	.943	.947

* $p = <0.05$. For all other values, $p = <0.01$.

Linear regressions of cesium–137 on total body weight and on lean body mass were obtained for each of the three groups by quarter year (table 6). Total body weight for the period October to December 1962 was remarkably similar to the regression obtained by Maycock et al (*3*), for 182 women and 21 men luminizers measured in Surrey between January 1958 and the end of 1959. This is not surprising since the mean cesium–137 body burden for an individual weighing 60 kg was 5.5 nCi in Maycock's study and 5.45 nCi in the present study. The similarity may be misleading, since the subjects in the former study comprised considerably more women (182) than men (21), while our subjects were 28 women and 52 men. Data presented in Maycock's report are insufficient to calculate mean cesium–137 per 60 kg body weight by sex. For our subjects, these data were 6.54 nCi for men and 5.10 nCi for women. The sex difference may in part be accounted for on the basis that fat comprised 8.5 percent more of the total body weight of women than of men. As noted in table 6, the regressions for cesium–137 on lean body mass had lower standard errors than for comparable regressions on total body weight.

[4] Standard deviation for the group of cesium–137 measurements.

Table 6. Linear regression of cesium–137 (nCi) on total body weight (kilograms) and on lean body mass (kilograms) by quarter year

Time period	Regression	S.E.
October to December 1962	0.048 TBW + 2.245	1.431
	0.095 LBM + 0.568	1.164
January to March 1963	0.081 TBW + 0.832	1.581
	0.161 LBM − 1.624	1.166
April to June 1963	0.126 TBW − 1.436	1.491
	0.174 LBM − 1.371	1.107

TBW, total body weight
LBM, lean body mass

Cesium–137 and diet

No consistent correlation for cesium–137/potassium ratios with intakes of food groups was found (table 7). Variations among intakes for each food category were great; for example, the first two groups of men had intakes of milk varying from 5 to 49 and 0 to 56 ounces per day, respectively. Intake ranges for milk for the remaining subject groups and for other food groups were generally smaller than the above two values.

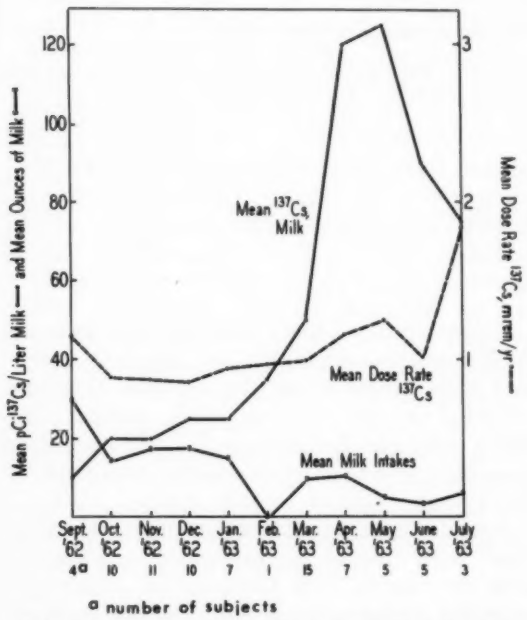
Only three of our groups of subjects showed positive, as well as high correlation with milk intake. However, when the seasonal variations of cesium–137/potassium ratio as well as extremes of milk intakes were considered, highly significant differences were obtained. Deviations from seasonal mean cesium–137/potassium ratios were calculated for 17 subjects having no intake of milk and 18 subjects with milk intakes equal to or greater than 20 ounces a day. A rank sum test of the differences was made. This provided a probability of less than two times in one hundred that the differences from the seasonal mean cesium–137/potassium ratio would have occurred by chance. Rank sum tests of the differences from seasonal mean ratios were similarly performed for food group intakes for meat, cereal, fruits and vegetables. Levels of comparisons were intakes of $\leq$ 4 ounces ($n = 16$) and $\leq$ 10 ounces ($n = 14$) for meat; $\leq$ 3 servings ($n = 13$) and $\geq$ 11 servings ($n = 11$) for cereals; and

Table 7. Median intakes of food groups and correlation with cesium–137/potassium ratios by sex and quarter year

Period and sex	Number of subjects	Milk (oz)	r	Milk and dairy products (oz)	r	Cereals (serving)	r	Animal protein foods (oz)	r	Fruits and vegetables (oz)	r
Men:											
Sept 1962	4	31.5	0.98	36.5	0.97	6.0	−0.91	6.0	0.02	18.0	0.51
Oct to Dec 1962	23	12.0	.30	19.0	.16	6.7	.23	6.7	−.02	14.0	.08
Jan to March 1963	14	4.0	.29	22.0	−.02	5.2	−.24	8.0	.37	14.0	−.38
April to June 1963	9	6.0	−.66	12.2	−.18	5.5	−.09	8.0	−.12	17.0	.30
Women:											
Oct to Dec 1962	8	12.0	−.12	28.5	−.14	4.6	−.55	5.5	.33	17.5	−.11
Jan to March 1963	9	9.5	.35	18.5	.38	4.5	.37	5.8	.13	12.0	.16
April to June 1963	8	4.5	.71	15.5	.10	6.6	−.63	6.0	−.60	17.0	−.20
July 1963	3	9.0	.99	20.0	.39	4.8	−.19	7.5	.54	11.0	.37

$\leq$ 9 ounces (n = 16) and $\geq$ 24 ounces (n = 15) for fruits and vegetables. Of these, only the latter was significant at the 2 percent level but not at the 1 percent level.

Mean intakes of milk and dose rates of cesium–137 for the 78 subjects having diet interviews have been plotted in figure 1 together with the mean cesium–137 content of milk from the San Franciso Bay area (*18*) by month. The few subjects studied during the first and last months precluded statistical evaluation; however, the described trends for cesium–137 content of milk and of subjects were consistent for these groups.



[a] number of subjects

Figure 1. Cesium–137 in milk from San Francisco Bay area, mean milk intakes, and mean cesium–137 dose rates for 78 Bay area subjects

A correlation between milk intake and cesium–137/potassium in the body has been found by Rundo (*19*) and by Anderson (*10*). Milk intake was considered responsible for about one-half of the average cesium–137 body burden for the nine subjects studied by Rundo in late 1958 and early 1959. The mean content was 51 pCi cesium–137/g potassium with about 25 pCi cesium–137/g potassium derived from food other than milk. In 1957, Anderson (*10*) observed average cesium–137 levels of 44 pCi/g potassium for people in different regions of the United States. Plotting these levels against cesium/potassium ratios in milk by regions, Anderson deduced that 23 pCi cesium–137/grams potassium was derived from food sources other than milk. Figure 2 presents similar analysis of our data. The conversion factor of 1.44 g potassium per liter milk was used[5]. The slope of the interrupted line, which did not employ the limited data for September 1962 and July 1963, has an intercept at 44 pCi cesium–137/g potassium. Following Anderson's reasoning, this amount can be considered the portion of cesium–137 derived from foods other than milk. Since the mean cesium–137/potassium ratio for subjects measured from October 1962 through June 1963 was 54 pCi, only about one-fifth of the cesium–137 body burden can be considered derived from milk. The relative contribution from milk was 23 percent in 1961 (*20*). For all subjects, shown by solid line in figure 2, the slope is the same as for subjects from October through June but the variance is six-fold greater, indicative of the wide range for cesium–137 over this time period.

[5] Agriculture Handbook No. 8, Composition of Foods. U.S. Department of Agriculture, December 1963. Watt, B. K., and A. L. Merrill.

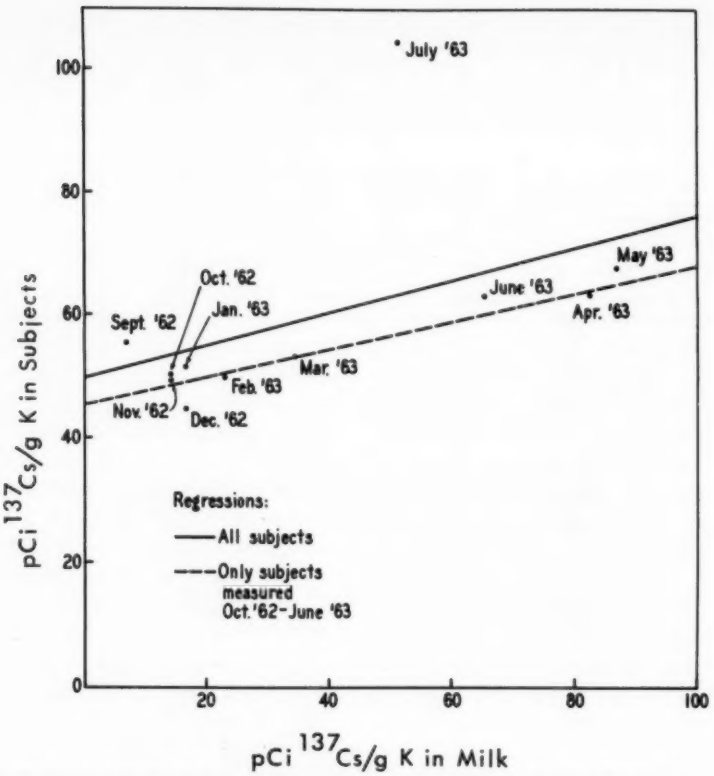


Figure 2. Levels of cesium–137 in subjects versus levels in milk by month

Total diet studies (including drinking water) for the San Franciso Bay area are analyzed at intervals for radionuclides (*21*, *22*). These studies show per capita cesium–137 intakes of 3.8 pCi/day for May 1962 (*21*), 53 pCi/day for August 1962 (*21*), 34 pCi/day for November 1962 (*21*), 33 pCi/day for December 1962 (*22*), 60 pCi/day for February 1963 (*21*), and 286 pCi/day for May 1963 (*21*). These data, based on the teen-age and Tri-City Diet studies represent figures for greater quantities of food than were consumed by the subjects of this study. Unfortunately, the present monitoring system of radioactivity in California diets had not been instituted at the time of this study; this would have afforded values more comparable to diets of our subjects. Composition of diets used for analysis in the Tri-City Diet studies are available and are based on average U.S. consumption per year (*22*). Comparison of the standard diet with subject mean intakes for food groups was made (table 8).

Table 8. Comparison of Tri-City diet with diet of subjects

Food group	Tri-City diet (oz/day, average)	All subjects (oz/day, average)
Milk	21.4	12.0
Milk and milk products	—	23.4
Poultry, fish, meat, egg	11.1	7.1
Bread, flour, cereal, etc.	9.4	6.3
Fruits and vegetables	23.3	16.8

Composition of diets used for the teen-age studies are not available, but possibly represent even larger quantities of food than are analyzed in the Tri-City Diet studies. The above analyses for cesium–137 are therefore somewhat in excess of quantities consumed by the average subject in this study.

An additional consideration must be recognized with respect to cesium–137 analyses of diets for the Tri-City Diet studies. Foods are prepared as for cooking, with inedible portions removed, but the foods were not actually cooked. Although little is known of the effects of food

processing and cooking on the cesium–137 content of food, there is indication that canning and freezing reduce the amount of this radionuclide (*23*).

Summary

Between September 1962 and July 1963, a time of rising cesium–137 content in the biosphere, whole body cesium–137 and potassium measurements were performed in an Argonne-type scintillation counter on 80 subjects; 52 men and 28 women. These data have been correlated with body composition estimates of body fat and lean body mass. Seventy-eight of the subjects had diet interviews. The intakes of food categories (milk, milk and other dairy products, animal protein foods, cereals, and fruits and vegetables) were correlated with *in vivo* cesium–137 measurements.

The results indicate whole body cesium–137 content correlates better with lean body mass than with total body weight. This is consistent with animal studies in which little cesium–137 has been found deposited in fat and with human autopsy specimens in which largest quantities are deposited in muscle. These results suggest calculations of dose rates for cesium–137 may be more meaningful if based on lean body mass rather than total body weight. The importance of this may be justified on the basis that persons with proportionately little body fat and large lean body mass may receive a greater dose-rate throughout the body than persons of comparable body weight but in whom the body composition parameters are proportionately opposite.

Diet intake of milk and of fruits and vegetables correlated significantly with *in vivo* cesium–137 measurements when the extremes of food intakes were considered. A regression equation was determined to calculate pCi cesium–137/g potassium in people from pCi cesium–137/g potassium measurements in milk. There appeared to be a time lag of 4 to 5 months between rising values of cesium–137 in milk and those in people, consistent with the biological half-life of cesium–137.

Acknowledgments

Grateful appreciation is given to H. E. Walsh, chief of the Bureau of Public Health Nutrition, California State Department of Public Health, to J. H. Lawrence, M.D., director of Donner Laboratory, and to J. L. Born, M.D., associate director of Donner Laboratory, University of California, Berkeley, for their interest and support of this study; to W. R. Gaffey, Ph.D., Division of Research, California State Department of Public Health, for statistical advice, and to Mrs. P. Stephenson, assistant public health statistician, Bureau of Public Health Nutrition, California State Department of Public Health for statistical assistance.

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Technical Notes

Personnel Monitoring of Radiologists During Fluoroscopy

Stewart C. Bushong, Thomas S. Harle, Magadalena Pogonowska and *John A. Burdine* [1]

A generally accepted observation has been that the greatest exposure to a diagnostic radiologist occurs during fluoroscopic procedures, even though he is normally wearing protective apparel during these procedures. Because the protective apparel perturbs the normal radiation field, there is some confusion and inconsistency regarding the placement of personal monitoring devices during fluoroscopy. The question arises frequently as to where is the most appropriate position on the body for a radiologist to wear his film badge.

Suggestions have been made that the film badge be worn on the belt under the protective-lead apron, at the shirt pocket level, on the upper arm, or on the head, neck or extremities (*1, 4*). The current recommendations of the National Council on Radiation Protection and Measurements are: "monitoring devices used to estimate whole body exposure normally should be worn on the chest or abdomen. When a protective apron is worn (e.g., during fluoroscopy), particular care should be taken in choosing the location of the monitoring device and in interpreting its reading" (*5*). This is a less specific recommendation than that previously made by the NCRP (*6*).

The purpose of this note is to describe data obtained from experiments designed to measure the dose equivalent to radiologists at various positions on the body.

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Method of procedure

Radiologists in the Diagnostic Section of the Ben Taub General Hospital, Houston, Tex., were monitored with commercially obtained film badges at 27 positions on the body during fluoroscopy. Table 1 lists these locations.

The same badges were worn for monthly periods beginning in the middle of January 1968 by 15 radiologists and therefore the data represent an average of the factors affecting dose equivalent of different radiologists; i.e., body size and stature, individual technique, etc. Eleven of the radiologists were residents in training. During each procedure, a 0.5 mm lead equivalent apron (Gardex Company, Model 232106) was worn and a similarly constructed protective glove (Wolf Branch Company, Model 271LF) was worn on the right hand. The left hand remained ungloved (many radiologists leave the left hand ungloved for easy manipulation of spot film controls) and was normally positioned on the control panel adjacent to the viewing screen. Only the gloved right hand was used for positioning the patient. Following each procedure, the radiologist would record his identity, the type of examination and the fluoroscopy time required.

All fluoroscopic procedures were performed in one of three examination rooms, each of which contained a Model No. 11–CKF–3 x-ray machine. These machines were normally operated at 85 kVp and 3 mA and produced an exposure rate of 4.5 R/min at the tabletop under these conditions. Protective lead curtains and a Bucky slot cover were used. A

Table 1. The dose equivalent of radiologists during fluoroscopy (mrem) January–April 1968

Location	First month	Second month	Third month	Total	Average (mrem/min)
Film badges:					
Control	0	0	0		
Screen panel	1,505	939	1,178	3,622	1.254
Screen panel [a]	1,853	934	978	3,765	1.304
Forehead	60	79	76	215	.074
Front collar	163	206	322	691	.239
Front collar [a]	6	18	6	30	.010
Back collar	17	31	14	62	.022
Shirt pocket	27	28	23	78	.027
Front belt	947	1,041	1,476	3,064	1.061
Front belt [a]	12	18	24	54	.019
Right belt	604	1,184	2,306	4,094	1.418
Right belt [a]	16	19	30	65	.023
Left belt	861	1,122	1,223	3,206	1.110
Left belt [a]	21	21	29	71	.025
Back belt	23	39	30	82	.028
Right knee	178	183	110	471	.163
Right knee [a]	64	31	20	115	.040
Right foot	33	35	40	108	.027
Wrist badges:					
Gloved hand palmar	2,526	1,661	1,335	5,522	1.912
Gloved hand palmar [a]	134	274	264	672	.233
Gloved hand dorsal	1,023	1,109	727	2,859	.990
Gloved hand dorsal [a]	83	214	274	571	.198
Bare hand palmar	3,539	3,640	1,990	9,169	3.175
Bare hand dorsal	5,727	6,152	2,363	14,242	4.932
Ring badges:					
Gloved hand palmar	(b)	2,305	1,132	3,437	1.805
Gloved hand palmar [a]	222	228	318	768	.266
Gloved hand dorsal	(b)	791	1,015	1,842	.968
Gloved hand dorsal [a]	212	185	(b)	397	.200
Bare hand palmar	(b)	5,221	(b)	5,221	5.227
Bare hand dorsal	(b)	5,912	(b)	5,912	5.919

[a] Shielded by protective apron or glove.
[b] Apparent light leak, no reading.

radiation protection survey showed that exposure levels around the table were low and there was no significant difference in the radiation environment of the three rooms.

Results

The results of these measurements for three monthly monitoring periods are shown in table 1. The dose equivalent values contained in this table are the values reported by the film badge vendor who claims an accuracy of ± 10 percent. These preliminary results indicate a consistency from one period to the next over the reporting interval. Specific conclusions regarding personnel monitoring during fluoroscopy may be drawn from these results.

Table 2 is a summary of the number of examinations performed and the relative time required by each of the total 794 examinations; only one radiologist performed more than 200 examinations and only three less than 100. The number of examinations per radiologists was fairly uniform.

Discussion

The data presented in table 1 show a wide range of values. The first column indicates the location of the film badge. The next three columns show the reported dose equivalent for each badge during each monitoring period. The next column is the sum of the data from the first three monitoring periods and the last column presents the average dose equivalent per minute of fluoroscopy time as reported in table 2.

Table 2. The number of fluoroscopic examinations performed and the relative time required for each

Location	First month	Second month	Third month	Total
U.G.I. exams/avg time (min) per exam	162/4.5	147/4.6	124/4.6	433/4.58
B.E. exams/avg time (min) per exam	67/2.7	86/2.9	64/3.6	217/3.06
G.B. exams/avg time (min) per exam	31/.95	29/.83	23/.83	83/.87
Other exams/avg time (min) per exam	19/2.1	17/2.7	25/3.1	61/2.66
Total number of exams	279	279	236	794
Total time (min) recorded average	983.6	1,001.3	895.2	2,880.0
Time (min)/exam	3.53	3.59	3.79	3.63

An evaluation of personnel monitoring procedures should account for the differences in recommended maximum permissible dose equivalent (MPD) for total body exposure and extremity exposure (*7, 8*). Total body exposure includes whole body, head and trunk, active blood-forming organs, gonads, or lens of the eyes. The accumulated MPD is 5 rems multiplied by the age in years beyond age 18. Further, the quarterly MPD is 3 rem, provided the accumulated MPD has not been exceeded. The MPD for the extremities, *i.e.*, hand and forearms, feet and ankles, is 25 rem/quarter, provided the annual dose equivalent does not exceed 75 rem.

Since the film badges located on the outside of the protective apparel indicate exposure to the protective apparel and not the radiologist, they were worn for demonstration and comparison purposes only. Under no circumstances should a monitoring device be worn on the outside of protective apparel. Therefore, the subsequent discussion is primarily concerned with total body monitoring and extremity monitoring that register exposure to the radiologist and not to the protective apparel.

Of the total body monitors, the film badge positioned on the front collar received the highest exposure and the badge located on the forehead received the second highest. The exposure received by the badge worn waist level on the back was higher than that received by any of the monitors positioned waist level under the protective apron. On the basis of these data, if only a single monitor is worn, it should be worn on the front collar since this is the region of the total body which receives the most exposure.

For the extremity monitors, the exposure of badges positioned on the right foot and knee was considerably less than that of the badges positioned on the hands and wrists; consequently, as one might expect, extremity monitoring should be concerned primarily with the upper extremities. Curiously enough, the monitors on the bare left hand received a higher exposure than the monitors positioned outside of the protective glove on the right hand. The reason for this is not clear. A resurvey of the x-ray machine showed a higher than expected exposure rate at the screen control panel. This was also indicated by the two film badges positioned on the screen control panel during fluoroscopy.

In order to view these data in perspective, the recorded dose equivalents must be evaluated in terms of the MPD applicable to that region of the body. It may be that the extremity exposures represent a greater fraction of the MPD than do any total body monitors and that, if only a single monitor were available, it should be worn on an extremity. These data are summarized in table 3. It was assumed that 75 fluoroscopic examinations were performed per week, 50 weeks per year, each examination requiring 3.63 minutes. The expected annual dose equivalent at each anatomical location was calculated on the basis of the average values shown in table 1. The MPD's used were 5 rem for total body and 75 rem for extremities.

The data presented in table 3 show that the bare hand required the highest fraction of the applicable MPD. They also show that the dose equivalent to the various other regions of the body, in relation to the applicable MPD, varies considerably. Therefore, regardless of where a film badge is worn, its position on the wearer's body should be a part of the personal monitoring record in order for that record to be interpreted meaningfully.

Table 3. The percent of maximum permissible dose equivalent at several anatomical regions

Location	(mrem/min)	(mrem/yr) [a]	Percent MPD
Bare finger dorsal	5.912	80,400	107
Bare wrist dorsal	4.932	67,100	90
Front collar	0.239	3,260	65
Forehead	.074	1,010	20
Shirt pocket [b]	.027	368	7.4
Left belt [b]	.025	335	6.7
Right belt [b]	.023	306	6.1
Front belt [b]	.019	255	5.1
Gloved finger palmar [b]	.266	3,510	4.7
Gloved wrist palmar [b]	.233	3,170	4.2

[a] Assuming 75 exam/week, 50 weeks/yr, 3.63 min/exam.
[b] Shielded by protective apron or glove.

There are few data in the literature with which to compare our results. Cowing and Spalding conducted radiation protection surveys on fluoroscopic installations in order to determine the minimum safe room size for this type of facility (*9*). They estimated an average exposure at the waist level of 11.4 mR/

exam and 4.77 mR/exam outside and inside the protective lead apron, respectively. The values obtained in our study were 4.24 mR/exam and 0.075 mR/exam outside and inside the apron, respectively. Jacobson, et al. performed an investigation of exposures to radiologists during fluoroscopy by positioning ionization-type pocket dosimeters on various body regions (*3*). They reported that the highest exposure was to the upper arm and that that was the desired location for a monitoring device. They further reported that film badges worn on the collar are often protected from direct radiation by the fluoroscopic screen and consequently this was not an appropriate place for a personnel monitoring device. Exposures to the upper arm were not investigated in the present study and direct comparisons cannot be made.

Conclusions

On the basis of these data, radiologists and technologists should wear a film badge on their collar outside of the protective lead apron during fluoroscopic examinations. Radiologists should glove both hands, but for radiologists who will not glove both hands, the ungloved hand should be monitored. Finger rings would be more desirable, but they are less reliable. For those installations that have thermoluminescence capabilities, its possible use for hand and wrist monitoring is suggested.

Representative products and manufacturers are named for identification only, and listing does not imply endorsement by the Public Health Service and the U.S. Department of Health, Education, and Welfare.

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SECTION I. MILK AND FOOD

In the determination of the internal exposure to man from environmental radiation sources, primary interest centers on radionuclides in the diet. Federal and State agencies are involved in efforts to monitor continuously the dietary intake of radionuclides. The most direct measure of radionuclide intake would be obtained through radioanalysis of the total diet. Difficulties in obtaining specific dietary data impede this approach. An alternate method entails the use of indicator foods to arrive at an estimate of the total dietary radionuclide intake.

Fresh milk is one such indicator food. It is consumed by a large segment of the U.S. population and contains most of the biologically significant radionuclides which appear in the diet. It also is one of the major sources of dietary intake for the short-lived radionuclides. For these reasons, fresh milk is the single food item most often used in estimating the intake of selected radionuclides by the general population and/or specific population groups. In the absence of specific dietary information, it is possible to approximate the total daily dietary intake of selected radionuclides as being equivalent to the intake represented by the consumption of 1 liter of fresh milk.

The Federal Radiation Council (FRC) has developed Radiation Protection Guides (RPG's) for controlling normal peacetime nuclear operations, assuming continuous exposure from intake by the population at large (*1–3*). The RPG's do not and cannot establish a line which is safe on one side and unsafe on the other; they do provide an indication of when there is a need to initiate careful evaluation of exposure (*3*). Additional guidelines are provided by the FRC Protective Action Guides (*4*) and by the International Commission on Radiological Protection (*5, 6*).

Data from selected national, international, and State milk and food surveillance activities are presented herein. An effort has been made to present a cross-section of routine sampling programs which may be considered of a continuing nature. Routine milk sampling has been defined as one or more samples collected per month.

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National and International Milk Surveillance

As part of continuing efforts to quantitatively monitor man's exposure to radionuclides, various national and international organizations routinely monitor radionuclide levels in milk. In addition to those programs reported below, *Radiological Health Data and Reports* coverage includes:

Program	Period reported	Last presented
Radiostrontium in milk, HASL	January-December 1967	August 1968

1. Pasteurized Milk Network
July 1968

National Center for Radiological Health and National Center for Urban and Industrial Health, PHS

The Public Health Service's Pasteurized Milk Network (PMN) is designed to provide nationwide surveillance of radionuclide concentrations in milk through sampling of major milk production and consumption areas. The present network of 63 stations (figure 1) provides data on milk in every State, Washington, D.C., the Canal Zone, and Puerto Rico. The most recent description of the sampling and analytical procedures employed by the PMN appeared in the January 1968 issue of *Radiological Health Data and Reports* (*1*). Reference should also be made to the February 1968 issue (*2*), in which several changes in the interpretation and reporting of data were introduced.

Table 1. Analytical errors associated with determinations of radionuclide concentrations in a milk sample

Nuclide	Concentration (pCi/liter)	Error [a] (pCi/liter)	Concentration (pCi/liter)	Error [a] (percent of concentration)
Strontium-89	<50	5	≥50	10
Strontium-90	<20	2	≥20	10
Iodine-131	<100	10	≥100	10
Cesium-137	<100	10	≥100	10
Barium-140	<100	10	≥100	10

[a] Two standard deviations.

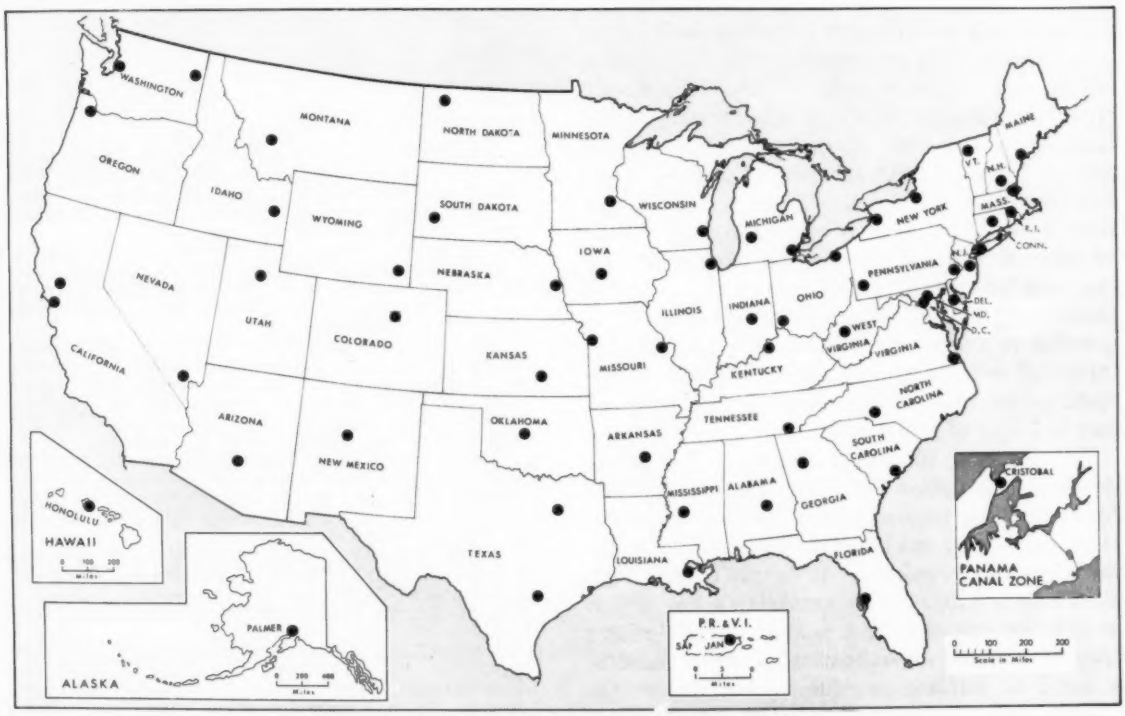

Figure 1. Pasteurized Milk Network sampling stations

Table 2. Average concentrations of radionuclides in milk for July 1968 and the 12-month period, August 1967 through July 1968

Sample location		Radionuclide concentration [a] (pCi/liter)									
		Strontium-89		Strontium-90		Iodine-131		Cesium-137		Barium-140	
		Aug 1967-July 1968	July 1968	Aug 1967-July 1968	July 1968	Aug 1967-July 1968	July 1968	Aug 1967-July 1968	July 1968	Aug 1967-July 1968	July 1968
Ala:	Montgomery	0	0	9	10	0	0	14	15	0	0
Alaska:	Palmer	0	0	5	8	0	0	15	13	1	0
Ariz:	Phoenix	0	0	1	0	0	0	2	2	0	0
Ark:	Little Rock	1	0	21	23	0	0	19	21	0	0
Calif:	Sacramento	0	0	3	0	0	0	5	2	1	0
	San Francisco	1	0	2	2	0	0	5	12	1	3
C. Z:	Cristobal	0	0	1	0	1	0	9	7	0	0
Colo:	Denver	1	0	4	4	0	0	6	13	0	0
Conn:	Hartford	NA	NA	10	14	0	0	12	15	0	0
Del:	Wilmington	NA	NA	11	12	0	0	8	9	0	0
D. C:	Washington	0	0	10	12	0	0	6	15	0	0
Fla:	Tampa	0	0	8	5	0	0	68	62	0	0
Ga:	Atlanta	0	0	14	14	0	0	20	20	0	0
Hawaii:	Honolulu	0	0	3	2	1	0	5	3	0	0
Idaho:	Idaho Falls	1	0	6	7	0	0	8	18	1	3
Ill:	Chicago	0	0	9	9	0	0	10	16	0	0
Ind:	Indianapolis	NA	NA	7	12	0	0	7	7	0	0
Iowa:	Des Moines	0	0	7	7	0	0	6	4	0	0
Kans:	Wichita	1	0	9	7	0	0	5	10	1	2
Ky:	Louisville	0	0	12	12	0	0	6	11	0	0
La:	New Orleans	0	0	22	21	0	0	24	29	0	0
Maine:	Portland	NA	NA	11	16	0	0	30	35	0	0
Md:	Baltimore	0	0	10	12	0	0	5	11	0	0
Mass:	Boston	0	0	12	17	0	0	25	38	0	0
Mich:	Detroit	NA	NA	9	14	0	0	12	12	0	0
	Grand Rapids	NA	NA	10	10	0	0	15	18	0	0
Minn:	Minneapolis	1	0	11	17	0	0	13	24	1	2
Miss:	Jackson	0	0	17	21	0	0	15	19	0	0
Mo:	Kansas City	2	6	8	5	0	0	4	3	1	0
	St. Louis	0	0	9	12	0	0	8	12	1	2
Mont:	Helena	0	0	5	6	0	0	8	15	1	2
Nebr:	Omaha	1	0	7	8	0	0	5	5	0	0
Nev:	Las Vegas	0	0	2	0	0	0	4	2	0	0
N. H:	Manchester	NA	NA	13	22	0	0	35	59	0	0
N. J:	Trenton	NA	NA	10	12	0	0	10	17	0	0
N. Mex:	Albuquerque	0	0	2	4	0	0	3	2	1	3
N. Y:	Buffalo	NA	NA	9	10	0	0	11	13	0	0
	New York city	NA	NA	11	18	0	0	14	21	0	0
	Syracuse [b]	NA	NA	7	12	0	0	8	4	0	0
N. C:	Charlotte	0	0	15	10	1	0	12	16	0	0
N. Dak:	Minot	3	7	11	11	0	0	11	12	0	0
Ohio:	Cincinnati	NA	NA	9	11	0	0	6	3	0	0
	Cleveland	NA	NA	10	14	0	0	9	12	0	0
Okla:	Oklahoma City	0	0	10	7	0	0	4	2	0	0
Ore:	Portland	1	0	7	11	0	0	15	19	1	0
Pa:	Philadelphia	NA	NA	9	14	0	0	8	16	0	0
	Pittsburg	NA	NA	12	18	0	0	14	20	0	0
P. R:	San Juan	0	0	4	4	0	0	11	8	0	0
R. I:	Providence	NA	NA	11	16	0	0	18	29	0	0
S. C:	Charleston	0	0	14	15	0	0	28	22	0	0
S. Dak:	Rapid City	1	0	10	8	0	0	10	17	0	0
Tenn:	Chattanooga	0	0	14	15	0	0	13	16	0	0
	Memphis	0	0	12	12	0	0	5	3	0	0
Tex:	Austin	0	0	4	3	0	0	3	0	0	0
	Dallas	0	0	7	9	0	0	6	8	0	0
Utah:	Salt Lake City	0	0	5	6	0	0	11	9	0	0
Va:	Norfolk	0	0	11	12	0	0	9	12	0	0
Vt:	Burlington	NA	NA	11	11	0	0	11	20	0	0
Wash:	Seattle	1	0	9	7	0	0	22	25	1	0
	Spokane	1	0	7	8	0	0	12	10	0	0
W. Va:	Charleston	0	0	12	14	0	0	4	2	0	0
Wisc:	Milwaukee	NA	NA	8	8	0	0	11	16	0	0
Wyo:	Laramie	0	0	4	4	0	0	7	15	0	0
Network monthly average		0	0	9	10	0	0	12	14	0	0

[a] See text for averaging procedure.
[b] 12-month average represents only 9 months data.
NA, no analysis.

Table 1 shows the approximate analytical errors (including counting error) associated with determinations of radionuclide concentration in milk. These errors were determined by comparing results of a large number of replicate analyses. Table 2 contains averages

for July 1968 and 12-month averages for the period, August 1967 through July 1968. The 12-month averages facilitate evaluations of population exposure with respect to the guidance provided by the Federal Radiation Council, which suggests average total daily intakes "averaged over periods of the order of a year," as an appropriate criterion (*3*). The average radionuclide concentrations are based on results obtained from samples collected weekly. Whenever weekly concentrations were less than or equal to the appropriate minimum detectable levels, zero was used for averaging purposes (*2*). At very low radionuclide concentrations this often results in averages lower than the minimum detectable concentration for a single sample, but any positive value reflects at least one weekly sample which was above the minimum detectable level. The minimum detectable concentration is defined as the measured concentration equal to the two-standard deviation analytical error. Accordingly, the minimum detectable concentrations in units of pCi/liter are: strontium–89, 5; strontium–90, 2; iodine–131, cesium–137, and barium–140, 10.

The average strontium–90 concentrations in pasteurized milk from selected cities are presented in figure 2.

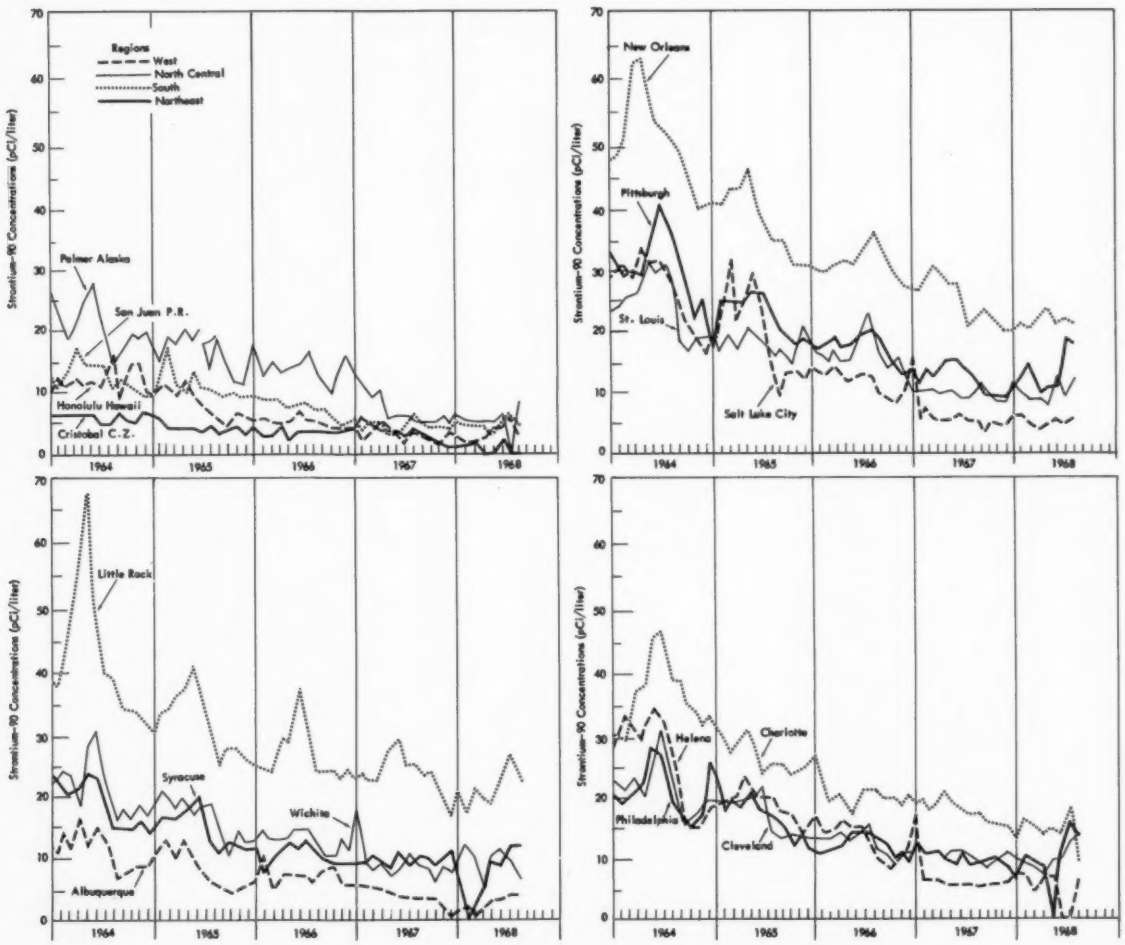

Figure 2. Strontium–90 concentrations in pasteurized milk, 1964–July 1968

2. Canadian Milk Network [1] July 1968

Radiation Protection Division
Department of National Health and Welfare

Since November 1955, the Radiation Protection Division of the Department of National Health and Welfare has been monitoring milk for radionuclide concentrations. Powdered milk was originally sampled, but liquid whole milk has been sampled since January 1963. At present, 16 milk sampling stations (figure 3) are in operation. Their locations coincide with air and precipitation sampling stations.

Milk samples are collected three times a week from selected dairies and are combined into weekly composites. The contribution of each dairy to the composite sample is directly proportional to the liquid volume of sales. Weekly spot check analyses are made for iodine–131, and monthly composites are analyzed for strontium–90, cesium–137, and stable calcium and potassium. The analytical procedures were outlined in the April 1968 issue of *Radiological Health Data and Reports* (4).

The July 1968 monthly average stronium–90, cesium–137, and stable calcium and potassium concentrations in Canadian whole milk are presented in table 3. Iodine–131 and stronium–89 concentrations were below minimum detectable levels.

[1] Prepared from August 1968 monthly report, "Data from Radiation Protection Programs," Canadian Department of National Health and Welfare, Ottawa, Canada.

Table 3. Stable elements and radionuclides in Canadian whole milk,[a] July 1968

Station	Calcium (g/liter)	Potassium (g/liter)	Strontium-90 (pCi/liter)	Cesium-137 (pCi/liter)
Calgary	1.14	1.4	8	20
Edmonton	1.10	1.5	8	23
Ft. William	1.10	1.5	20	37
Fredericton	1.06	1.6	18	31
Halifax	1.12	1.4	14	30
Montreal	1.07	1.4	10	23
Ottawa	1.12	1.4	10	23
Quebec	1.04	1.4	11	29
Regina	1.21	1.3	8	16
St. John's, Nfld.	1.12	1.5	34	60
Saskatoon	1.10	1.6	8	28
Saulte Ste. Marie	1.07	1.5	9	37
Toronto	1.10	1.5	4	15
Vancouver	1.12	1.4	16	52
Windsor	1.12	1.5	5	10
Winnipeg	1.12	1.6	10	21
Average	1.11	1.5	12	28

[a] Due to insignificant levels of strontium-89 the reporting of this radionuclide has been discontinued.

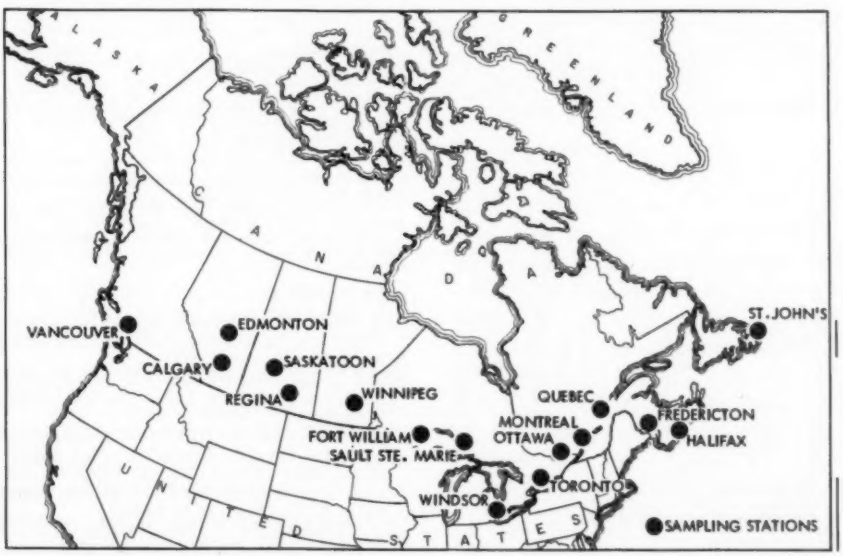

Figure 3. Canadian milk sampling stations

3. Pan American Milk Sampling Program July 1968

Pan American Health Organization and *U.S. Public Health Service*

The Pan American Health Organization (PAHO), in collaboration with the U.S. Public Health Service (PHS), furnishes assistance to health agencies in the American republics engaged in developing national radiological health programs.

Under a joint agreement between agencies, milk sampling activities are conducted by a number of PAHO-member countries (figure 4). The milk sampling program was begun in August 1963, with a sampling station in Caracas, Venzuela. Between April 1964 and August 1964, stations were added in Jamaica at Kingston, Montego Bay, and Mandeville, and in the period, July to September 1966, Ecuador, Columbia, and Chile joined the program with stations at Guayaquil, Bogata, and Santiago, respectively.

Figure 4. Pan American Milk Sampling Program locations

Sampling procedures

Sampling frequency varies according to local procedures. Collected samples are preserved with formaldehyde, composited monthly and sent to the PHS Southeastern Radiological Health Laboratory for analysis. In the case of Jamaica, the monthly composite is collected on a rotating basis from one of the three principal milk areas: Montego Bay (Montpelier), Mandeville, or Kingston (Spanish Town).

Analytical procedures

Iodine–131, cesium–137, and barium–140 concentrations are determined by gamma scintillation spectrometry. Strontium–89 and strontium–90 are determined radiochemically. Analytical errors are discussed under "Pasteurized Milk Network, September 1967" in the January 1968 issue of *Radiological Health Data and Reports.*

Data presentation

Table 4 presents stable potassium, strontium–90, and cesium–137 monthly concentrations for July 1968.

Table 4. Stable element and radionuclide concentrations in Pan American milk,[a] July 1968

Sampling station	Number of samples	Potassium (g/liter)	Strontium-90 [b] (pCi/liter)	Cesium-137 [b] (pCi/liter)
Chile: Santiago	1	1.5	0	0
Ecuador: Guayaquil	1	1.3	0	0
Jamaica: Kingston	1	1.5	6	65
Venezuela: Caracas	1	1.6	3	0
Canal Zone: Cristobal [c]	5	1.5	0	7
Puerto Rico: San Juan	5	1.6	4	8

[a] All strontium-89 results were ≤ 5 pCi/liter; iodine-131 and barium-140 results were all < 10 pCi/liter.

[b] Strontium-90 single sample results ≤ 2 pCi/liter and cesium-137 single sample results ≤ 10 pCi/liter are reported as 0.

[c] For comparison, the average radionuclide concentrations in Pasteurized Milk Network samples collected at Cristobal, Canal Zone, andSan Juan, Puerto Rico, are presented.

REFERENCES

(1) PUBLIC HEALTH SERVICE. Pasteurized Milk Network, September 1967. Radiol Health Data Rep 9:20–23 (January 1968).

(2) PUBLIC HEALTH SERVICE. Pasteurized Milk Network, October 1967. Radiol Health Data Rep 9:86–89 (February 1968).

(3) FEDERAL RADIATION COUNCIL. Background material for the development of radiation protection standards, Report No. 2. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (September 1960).

(4) DEPARTMENT OF NATIONAL HEALTH AND WELFARE, RADIATION PROTECTION DIVISION. Canadian milk network, August 1966. Radiol Health Data Rep 7:702–703 (December 1966).

State Milk Surveillance Activities

Considerable progress has been made by the State health departments in initiating or expanding environmental surveillance activities in radiological health. Many of the States now have comprehensive environmental surveillance programs and self-sustaining radiological health laboratories.

The continuing efforts of State health departments in the analysis and monitoring of radionuclides in milk complement Federal milk surveillance activities. State milk surveillance activities are continually undergoing developmental changes. The results presented herein are representative of current surveillance activities directed at the use of milk as an indicator of dietary intake of radioactivity.

Figure 1 shows the States which report milk surveillance activities in *Radiological Health Data and Reports*. Data from these State activities have been updated through July 1968. Commencing with the December 1968 issue of *Radiological Health Data and Reports*, milk surveillance data will be reported on a monthly basis for all State, Federal, and International programs.

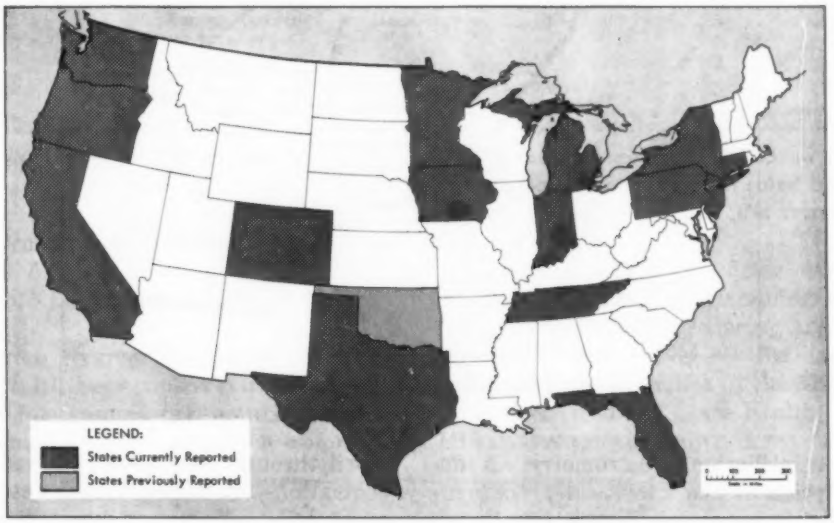

Figure 1. State milk surveillance activities

1. California Milk Network April–July 1968

Division of Environmetal Sanitation
State of California, Department of Public Health

Surveillance of specific radionuclides in milk is one phase of the California Department of Health program on radiation control. This milk monitoring function is conducted by the Department's Bureau of Radiological Health at 10 major milksheds (figure 2).

In January 1960, the eight original sampling locations were chosen by the State Department of Agriculture so as to be representative of milk consumed by a high percentage of the State's population. The Del Norte and Mendocino milksheds were added to the program in March 1962 and since that time, weekly, biweekly or monthly sampling of pasteurized milk has been conducted in 10 milkshed areas of the State. A description of the various California milksheds was presented earlier by Heslep and Cornish (*1*).

Strontium–89 and strontium–90 concentrations are determined radiochemically. Potassium–40, iodine–131, cesium–137, and barium–140 in whole fluid milk are determined by

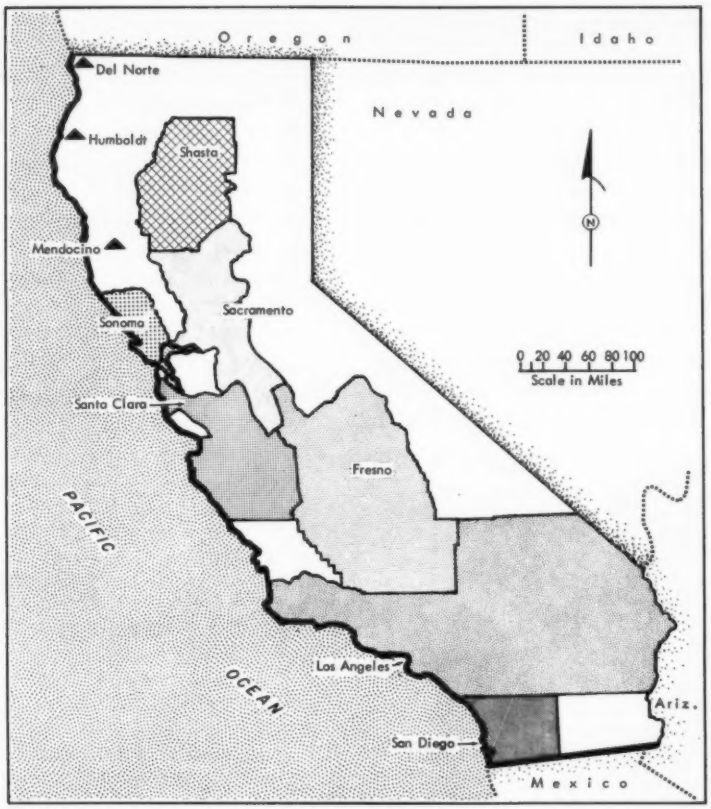

Figure 2. California milksheds

gamma-ray scintillation spectrometry. A detailed description of the analytical procedures was presented in an earlier report (*2*).

The monthly calcium, potassium and radionuclide concentrations in California pasteurized milk are given in table 1 for the period of April through July 1968. All iodine–131 concentrations remained below detectable levels of 10 pCi/liter during this period.

Network average strontium–90 and cesium–137 concentrations are presented graphically in figure 3.

Table 1. Stable elements and radionuclide concentrations in California milk, April–July 1968

Sampling location	Calcium (g/liter)				Potassium (g/liter)				Strontium-89 (pCi/liter)				Strontium-90 (pCi/liter)				Cesium-137 (pCi/liter)			
	Apr	May	June	July	Apr	May	June	July	Apr	May	June	July	Apr	May	June	July	Apr	May	June	July
Del Norte	1.36	1.32	1.34	1.25	1.5	1.5	1.6	1.6	16	6	11	4	19	20	19	15	24	19	21	15
Fresno	1.22	1.15	NA	1.08	1.6	1.5	1.5	1.5	2	ND	1	ND	1	2	1	2	ND	9	ND	ND
Humboldt	1.15	1.21	1.16	1.13	1.5	1.5	1.5	1.5	10	ND	3	ND	1	7	5	3	ND	12	13	9
Los Angeles	1.11	1.09	1.04	1.04	1.6	1.6	1.7	1.4	ND	2	1	ND	3	2	1	2	ND	ND	ND	ND
Mendocino	NA	1.29	1.06	1.08	1.5	1.5	1.6	1.5	2	3	1	ND	5	3	3	2	16	ND	ND	ND
Sacramento	1.16	1.18	1.21	1.12	NA	1.5	1.5	1.6	5	1	ND	ND	2	3	3	2	NA	10	12	11
San Diego	1.10	1.05	1.13	1.06	1.5	1.5	1.6	1.6	1	ND	ND	ND	1	1	1	1	8	ND	ND	6
Santa Clara	1.21	1.00	1.09	1.13	1.5	1.3	1.5	1.6	2	ND	ND	ND	1	2	2	1	8	19	ND	6
Shasta	1.11	1.15	1.11	1.06	1.6	1.5	1.6	1.5	ND	1	ND	ND	4	3	4	3	ND	ND	14	ND
Sonoma	1.15	1.11	1.14	1.10	1.6	1.5	1.6	1.6	5	ND	ND	ND	4	4	2	2	ND	12	10	ND

NA, no analysis.
ND, nondetectable.

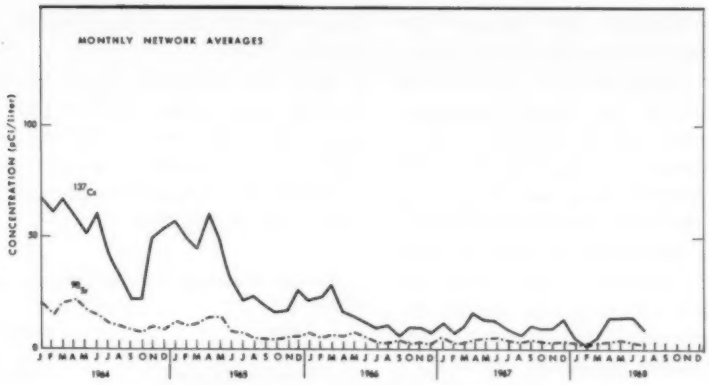

Figure 3. Radionuclide concentrations in California milk 1964–July 1968

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
October–December 1967	June 1968
January–March 1968	September 1968

2. Colorado Milk Network July 1968

Air, Occupational and Radiation Hygiene Division
Colorado State Department of Public Health

The Radiation Hygiene Section of the Colorado State Health Department initiated analysis of milk for gamma-ray emitting radionuclide in January 1962. Initially a composite milk sample from the major producers supplying the Denver area was collected by the Denver City and County Health Department for the State.

In August 1962, the State expanded this program to include the sampling of raw milk from the major milk producing areas supplying the entire State. The routine sampling rate depends on the activities of the Milk, Food and Drug Section of the State Health Department. Milkshed areas are shown in figure 4.

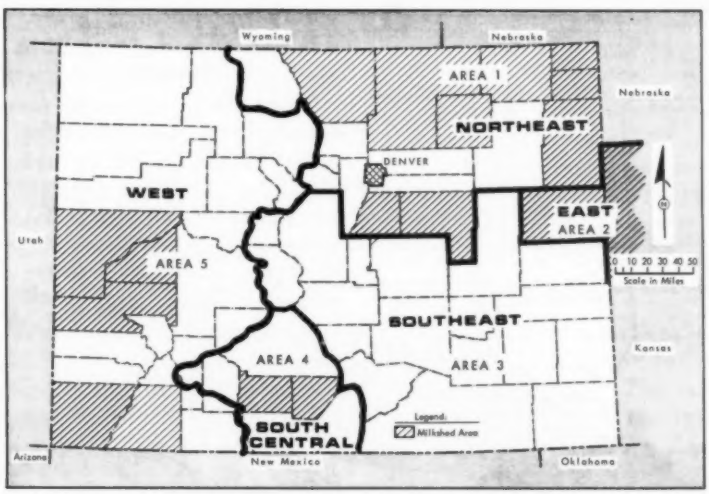

Figure 4. Colorado milk sampling stations

Analyses are performed for iodine–131, barium–lanthanum–140, cesium–137 and potassium by gamma-ray spectrometry. Employed in this procedure is a 4- by 5-inch diameter NaI(Tl) crystal housed in a modified office safe lined with 2 inches of lead and a 512 multichannel pulse-height analyzer using a typewriter readout. Samples and backgrounds are counted for 40 minutes in a 2 quart (1,892 ml) plexiglass Marinelli beaker. Calculation is by the matrix method (*3*) and the minimum detectable concentrations are: iodine–131, 15 pCi/liter; barium-lanthanum–140, 21 pCi/liter; cesium–137, 16 pCi/liter; and potassium, 0.25 g/liter.

Four milk samples were collected and counted during July 1968. Iodine–131, barium-lanthanum–140 and cesium–137 concentrations were below their respective minimum detectable concentrations. Potassium concentrations averaged 1.5 ± 0.2 (2σ) g/liter.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
January–March 1968	July 1968
April–June 1968	October 1968

3. Connecticut Milk Network April–July 1968

Connecticut State Department of Health

The Connecticut State Department of Health has been monitoring pasteurized milk for strontium–89 and strontium–90 since April 1960. In May 1962, the program was expanded to include the determination of gamma-emitting radionuclides in milk.

The sampling program is flexible in nature, providing for sampling in five areas of the State (figure 5). At the present time, weekly samples representative of milk sold in the central area of the State are collected and analyzed for strontium–89, strontium–90, and gamma-ray emitters. Concentrations of iodine–131 are determined as an indication of the presence of radioactivity of recent origin.

Table 2. Radionuclide concentrations in central Connecticut pasteurized milk, April–July 1968

Month	Radionuclide concentration (pCi/liter)			
	Strontium-89	Strontium-90	Iodine-131	Cesium-137
April	NA	7	<10	10
May	NA	8	<10	<10
June	NA	10	<10	15
July	NA	NA	<10	20

NA, no analysis.

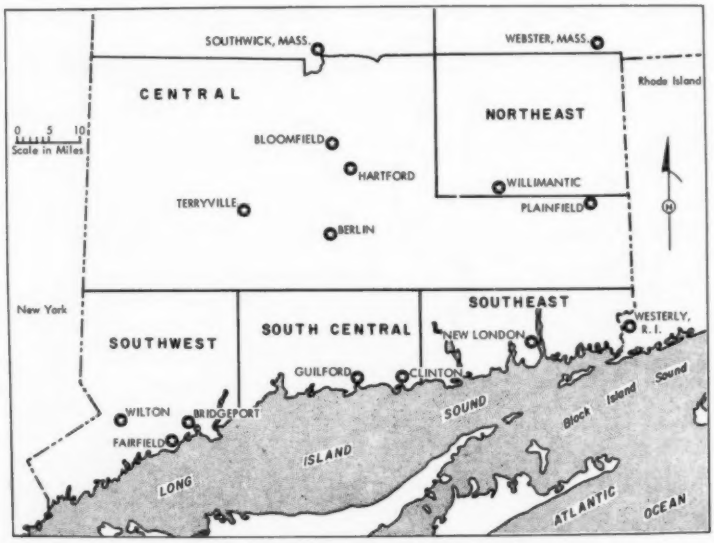

Figure 5. Connecticut pasteurized milk sampling areas

Figure 6. Radionuclides in Connecticut pasteurized milk 1964–July 1968

Strontium–89 and strontium–90 are determined by chemical separation. Iodine–131 and other gamma-ray emitters are determined by gamma-ray scintillation spectroscopy.

The monthly average concentrations of strontium–89, strontium–90, iodine–131, and cesium–137 in central Connecticut pasteurized milk are presented in table 2. These results are presented graphically in figure 6.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
October–December 1967	May 1968
January–March 1968	August 1968

4. Florida Milk Network July 1968

Division of Radiological Health
Florida State Board of Health

The Florida State Board of Health began sampling raw milk for iodine–131 analysis in two major areas of the State in November 1962. The program has since been expanded to include the analysis of milk for strontium–89, strontium–90, cesium–137, barium–140 and potassium, in addition to iodine–131. Analysis for strontium–89 was made until 1965, but due to extremely low levels has been discontinued since that time. Monthly milk sample collection procedure of obtaining milk from randomly selected farms in each of the six regions of the State (figure 7), was redesigned in July 1968. Beginning in July 1968, a 1-gallon raw milk sample is collected monthly from a major processing plant in each of the regions referenced above. The milk produced in each region is generally processed and consumed in that region. The procesing plant from which the milk sample is obtained was selected on its percentage contribution to the total milk market.

Figure 7. Florida milk sampling areas

The sample of milk is collected in each region on Monday or Tuesday following the first Sunday of each month. The maximum age of any portion of the milk making up the sample is 72 hours. The samples are sent to the State Board of Health Radiological Laboratory in Orlando for analyses. The samples are ana-

Table 3. Stable element and radionuclide concentration [a] in Florida raw milk, July 1968

Sampling location	Potassium (g/liter)	Radionuclide concentrations (pCi/liter)	
		Strontium-90	Cesium-137
	July	July	July
West	1.7	12	23
North	1.6	20	46
Northeast	1.6	11	68
Central	1.6	10	184
Tampa Bay area	1.6	7	55
Southeast	1.6	13	108

[a] Barium-140 and iodine-131 concentrations remained below 10 pCi/liter for this period.

lyzed and corrected for decay to the time and date of collection.

Strontium–90 is determined by the ion exchange method developed by Porter et al (*4*). Iodine–131, cesium–137, barium–140 and potassium are determined by gamma-ray spectrometry (*5*).

Stable element and radionuclide concentrations for July 1968 are presented in table 3.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
January–March 1968	July 1968
April–June 1968	October 1968

5. Indiana Milk Network April–July 1968

Bureau of Environmental Sanitation
Indiana State Board of Health

The Indiana State Board of Health began sampling pasteurized milk for radionuclide analysis in September 1961. The State was geographically divided into five major milksheds; northeast, northwest, central, southeast, and southwest (figure 8). One large dairy within each milkshed was assumed to be representative for sampling purposes.

The milk samples are analyzed monthly for strontium–89 and strontium–90. Cesium–137, iodine–131, and barium–140 are analyzed weekly for at least two of the milksheds. When iodine–131 concentrations exceed 100 pCi/liter, the sampling frequency is increased. From August 1963 to April 1966, because of the continued low concentrations of short-lived radionuclides, the sampling frequency was once a month for the northeast, southeast, and southwest milksheds.

Strontium–89 and strontium–90 concentrations in milk samples are determined by ion exchange separation (*4, 6*) while cesium–137, iodine–131, and barium–140 are determined by gamma-ray scintillation spectrometry (*7*).

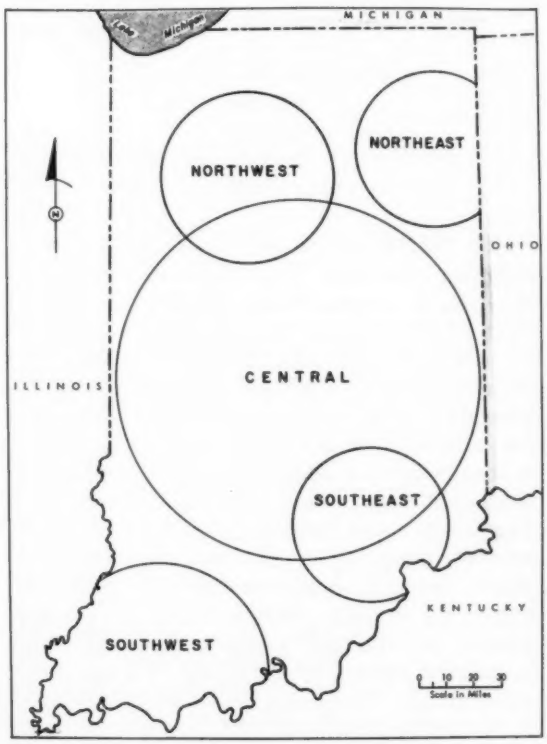

Figure 8. Indiana pasteurized milk sampling areas

The monthly stable element and radionuclide concentrations in Indiana pasteurized milk are

Table 4. Stable element and radionuclide concentrations in Indiana milk [a] April–July 1968

Sampling location	Calcium (g/liter)				Potassium (g/liter)				Strontium-90 (pCi/liter)				Cesium-137 (pCi/liter)			
	Apr	May	June	July	Apr	May	June	July	Apr	May	June	July	Apr	May	June	July
Northeast	1.13	NA	1.29	1.16	1.5	1.6	1.5	1.6	7	7	11	10	10	10	10	10
Southeast	1.13	NA	1.28	1.13	1.7	1.6	1.4	1.7	9	11	13	11	10	20	20	5
Central	1.18	NA	1.15	1.16	1.5	1.5	1.5	1.7	7	9	9	9	5	10	10	5
Southwest	1.24	NA	1.25	1.18	1.6	1.5	1.6	1.6	7	12	13	12	10	15	15	15
Northwest	1.20	NA	1.18	1.18	1.5	1.5	1.5	1.6	8	9	11	9	10	10	15	10

[a] All strontium-89 concentrations were 0 for this period.

presented by sampling locations in table 4 for April through July 1968. Barium–140 and iodine–131 concentrations remained below detectable levels of 10 pCi/liter during this period.

The monthly network average concentrations of strontium–89, strontium–90, and cesium–137 are presented graphically in figure 9.

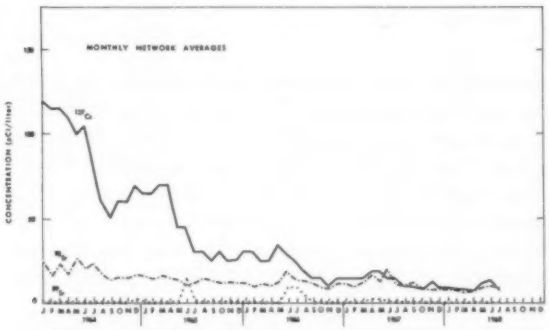

Figure 9. Radionuclide concentrations in Indiana pasteurized milk, 1964–July 1968

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
October–December 1967	May 1968
January–March 1968	August 1968

6. Iowa Milk Network April–July 1968

State Hygienic Laboratory and the Iowa State Department of Health

In Iowa, radiological health activities are conducted jointly by the State Department of Health and the State Hygienic Laboratory, with the State Hygienic Laboratory performing the surveillance and analytical functions.

In August 1962 the State Hygienic Laboratory of Iowa began sampling milk for iodine–131. In May 1964 this routine surveillance was expanded to include cesium–137 and strontium–90.

One gallon samples are collected from 4 stations, selected to give a broad coverage of milk production areas in the State (figure 10). Producers furnishing milk to the Spencer bottling area are quite restricted to that northwest part of the State and the majority of milk

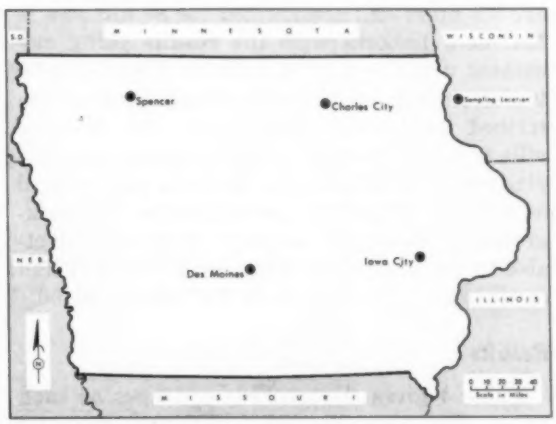

Figure 10. Iowa milk sampling locations

Table 3. Radionuclide concentrations in Iowa milk, April–July 1968

Sampling location	Concentration (pCi/liter)											
	Strontium-90				Cesium-137				Iodine-131			
	April	May	June	July	April	May	June	July	April	May	June	July
Iowa City	7	8	7	NA	<10	<10	<10	<10	<10	<10	<10	<10
Des Moines	7	7	NA	NA	<10	<10	<10	<10	<10	<10	<10	<10
Spencer	7	7	NA	NA	<10	<10	<10	<10	<10	<10	<10	<10
Charles City	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

NA, no analysis.

bottled in Iowa City comes from six counties in east central Iowa. The Des Moines milkshed comprises approximately 60 counties covering about two thirds of the State radiating out of Des Moines in all directions. The Charles City bottling area covers primarily north central Iowa. At present the Iowa City and Des Moines stations are sampled weekly and the Spencer and Charles City stations are sampled monthly. This sampling frequency is increased when nuclide concentrations warrant closer surveillance. The samples are forwarded to the State Hygienic Laboratory at the University of Iowa, Iowa City for analysis.

Analytical procedures

Iodine–131 and cesium–137 together with barium–lanthanum–140 and potassium–40 are determined by gamma-scintillation spectrometry using a 4- by 4-inch NAI (Tl) crystal and 512 channel pulse-height analyzer. All samples are 3.5 liters and are counted for 80 minutes in Marinelli beakers with the results being calculated using a 4 by 4 matrix. Strontium–90 is determined by an ion-exchange system described by Porter, et al (*14*). One liter of milk is passed through an ion exchange column; yttrium–90 is eluted from the resin and counted as yttrium oxalate in an automatic low background proportional counter. Minimum detectable limits are 10 pCi/liter for iodine–131 and cesium–137 and 2 pCi/liter for strontium–90.

Results

Table 4 gives the monthly averages at each of the four locations for April-July 1968 and figure 11 shows graphically the overall network average monthly results for the same period. During this period it can be seen that the concentration levels of cesium–137 and strontium–90 showed a decreasing trend. The only significant amount of iodine–131 was present during the month of June 1965.

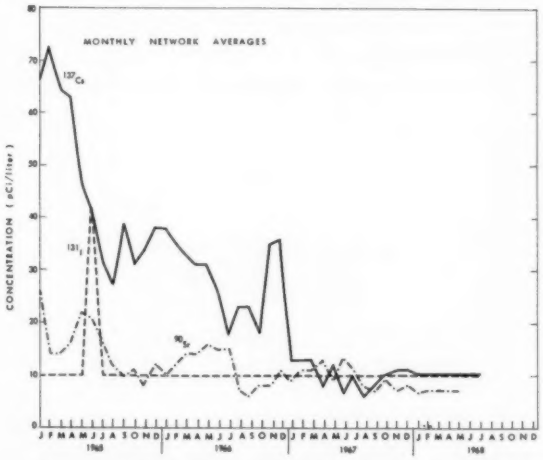

Figure 11. Radionuclide concentrations in Iowa milk, 1965–July 1968

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
October–December 1967	May 1968
January–March 1968	August 1968

7. Michigan Milk Network April–July 1968

Division of Occupational Health
Michigan Department of Health

The Michigan Department of Health began sampling pasteurized milk for radionuclide analyses in November 1962. Under this program, weekly pasteurized milk samples are collected in the seven major milk producing areas in the State: Charlevoix, Detroit, Grand Rapids, Lansing, Marquette, Monroe, and Saginaw (figure 12). Milkshed samples are composites of dairies in proportion of sales volumes.

Strontium–90 concentrations are determined by an ion exchange method (*8*). Potassium-40, iodine–131, cesium–137, and barium-lanthanum–140 concentrations are determined by gamma-ray scintillation spectrometry (*8*).

Table 6 presents the monthly average radionuclide concentrations in Michigan pasteurized

Table 6. Radionuclide concentrations in Michigan pasteurized milk, April–July 1968

Sampling location	Month	Potassium (g/liter)	Strontium-90 (pCi/liter)	Iodine-131 (pCi/liter)	Cesium-137 (pCi/liter)
Charlevoix	April	1.6	4	<14	10
	May	NA	NA	NA	NA
	June	NA	NA	NA	NA
	July	NA	NA	NA	NA
Detroit	April	1.6	4	<14	10
	May	1.6	4	<14	11
	June	1.5	NA	<14	14
	July	1.6	7	<14	11
Grand Rapids	April	1.6	5	<14	12
	May	1.6	5	<14	10
	June	1.6	NA	<14	13
	July	1.6	5	<14	15
Lansing	April	1.6	2	<14	7
	May	1.6	4	<14	10
	June	1.6	NA	<14	9
	July	1.6	5	<14	11
Marquette	April	1.6	7	<14	19
	May	1.6	8	<14	19
	June	1.5	6	<14	27
	July	1.6	1	<14	40
Monroe	April	1.6	3	<14	6
	May	1.6	3	<14	5
	June	1.6	3	<14	5
	July	1.6	7	<14	8
Bay City	April	1.6	4	<14	10
	May	NA	NA	NA	NA
	June	1.6	NA	<14	13
	July	1.6	5	<14	15

NA, no analysis.

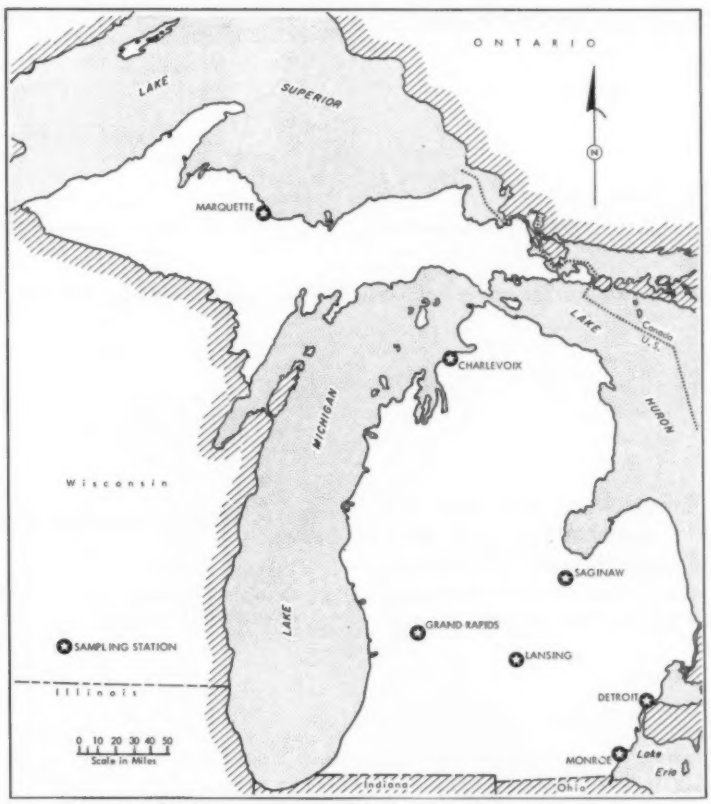

Figure 12. Michigan pasteurized milk network sampling locations

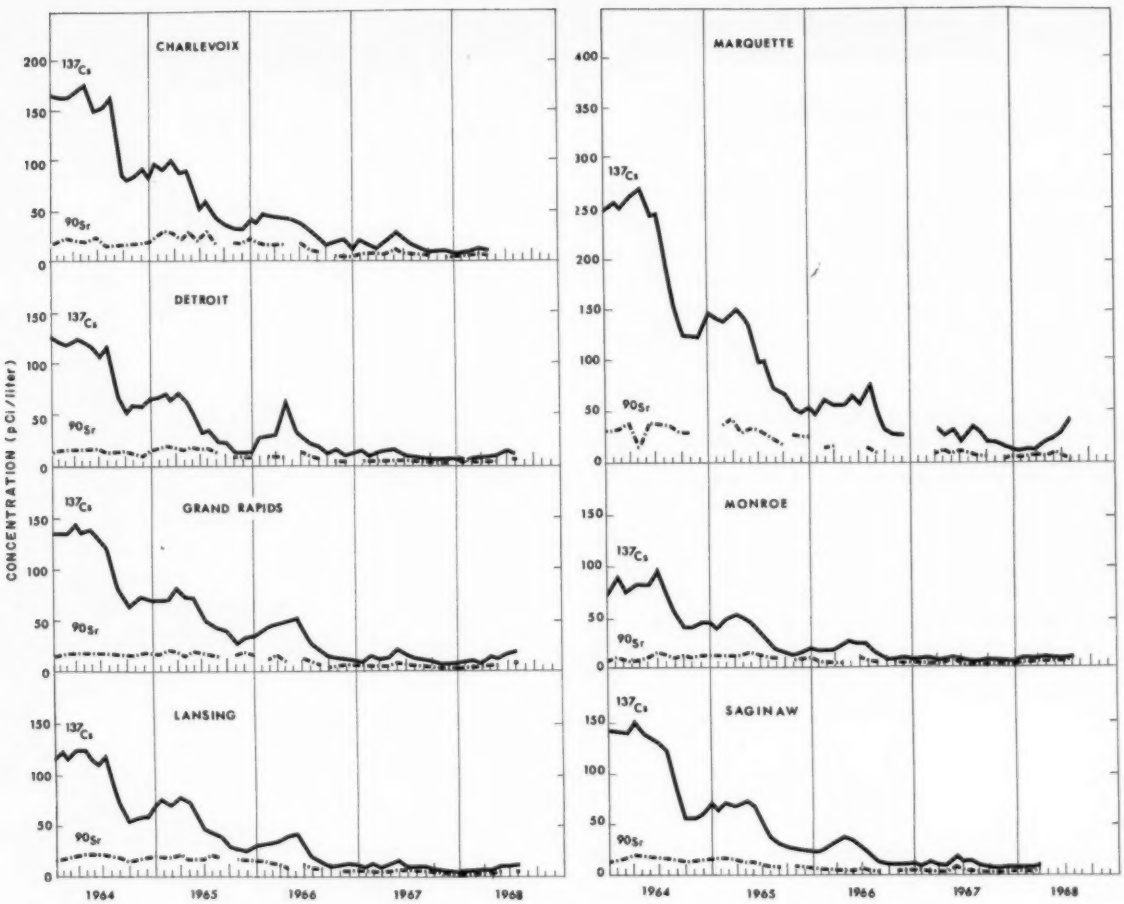

Figure 13. Radionuclide concentrations in Michigan pasteurized milk, 1964–July 1968

milk. Iodine–131 levels were less than the minimum detectable radioactivity (14 pCi/liter) for the period at all stations. Strontium–90 and cesium–137 concentrations are presented graphically in figure 13 to show general trends.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
October–December 1967	May 1968
January–March 1968	August 1968

8. Minnesota Milk Network April–July 1968

Division of Environmental Health
Minnesota Department of Health

In September 1958, the Minnesota Department of Health initiated a pasteurized milk network to monitor strontium–90 concentrations. Monitoring of iodine–131 concentrations commenced in October 1961 and of cesium–137 concentrations in July 1963. Until recently, one-liter samples were collected from eight sampling locations in milksheds geographically the same as the Minnesota health districts (figure 14) and analyzed for strontium–90, iodine–131, and cesium–137. The size of the sample has been increased to 2 quarts for more accurate determinations. The 2-quart samples of processed Grade A fluid milk are collected in the cities where the Minnesota Health Department district offices are located.

Strontium–90 concentrations are determined radiochemically, while iodine–131 and cesium–137 concentrations are determined by gamma ray scintillation spectrometry. The analytical procedures are presented in the semiannual report of the Minnesota Department of Health and the Rural Cooperative Power Association (*9*).

Strontium–90, and cesium–137 concentrations in milk are given for April through July 1968 in table 7, and are presented graphically by milkshed in figure 15 for the period, 1964 through July 1968. Iodine–131 concentrations were less than 10 pCi/liter in all 24 samples.

Table 7. Radionuclide concentrations in Minnesota pasteurized milk, April–July 1968

Station	Radionuclide concentrations (pCi/liter)							
	Strontium-90				Cesium-137			
	Apr	May	June	July	Apr	May	June	July
Bemidji	15	16	16	19	28	30	30	21
Mankato	6	5	5	8	15	11	7	<4
Rochester	7	10	11	11	10	7	10	22
Duluth	19	18	24	26	40	26	38	44
Worthington	6	5	6	8	12	5	8	15
Minneapolis	10	13	15	18	15	14	13	26
Fergus Falls	8	18	8	12	13	13	15	15
Little Falls	8	9	12	10	15	15	11	21

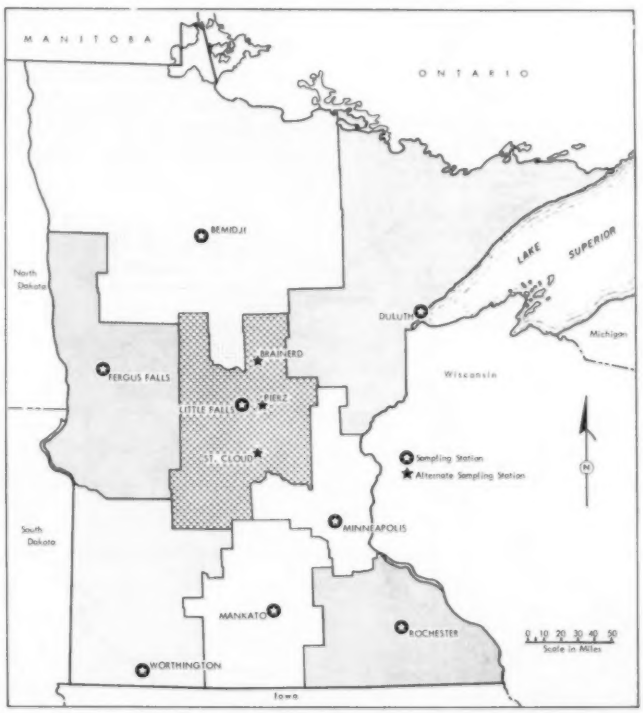

Figure 14. Minnesota milk sampling locations

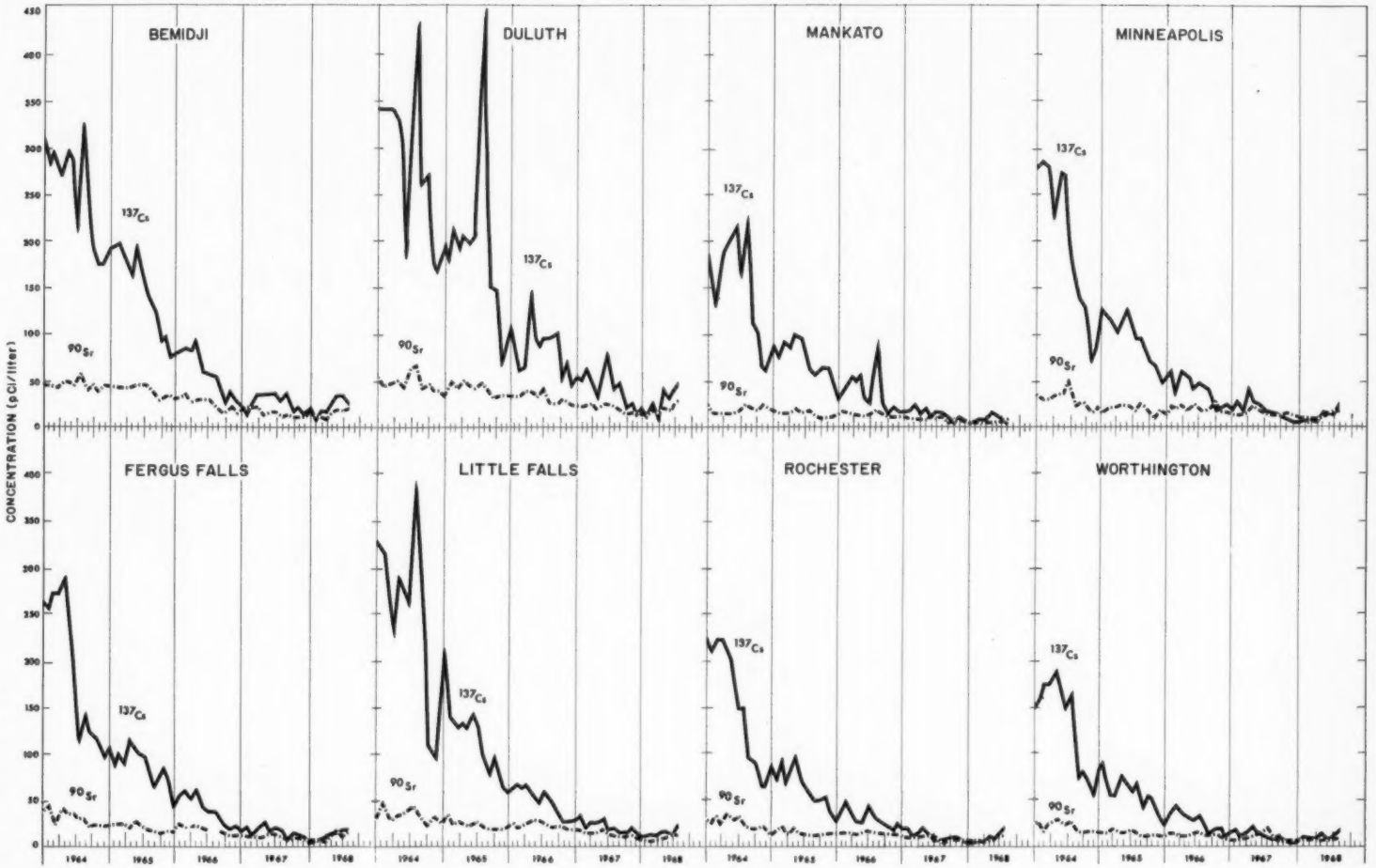

Figure 15. Radionuclide concentrations in Minnesota milk, 1964–July 1968

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
October–December 1967	May 1968
January–March 1968	August 1968

9. New York Milk Network April–July 1968

Division of General Engineering and Radiological Health
Department of Health, State of New York

Pasteurized milk samples collected routinely from six cities (figure 16 are analyzed for strontium–89, strontium–90, iodine–131, cesium–137 and barium-lanthanum–140 by the from six cities (figure 16) are analyzed for New York State Department of Health. At Buffalo and Newburgh, milk samples are collected daily from processing plants and composited weekly for radiochemical analyses. At Messena, and Syracuse daily samples are composited over a 2-week period and then analyzed. In New York City, a milk sample representing the total milk supply for 1 day is analyzed weekly. The Albany sample, taken at a marketing point, is analyzed daily for iodine–131 and other gamma-ray emitting radionuclides before being composited into a weekly sample. In the event that any sample contains iodine–131 concentrations exceeding 100 pCi/liter, increased surveillance is undertaken.

Gamma-ray emitting radionuclides in milk are determined by scintillation spectrometry. Radioiodine is selectively removed in an anion exchange resin and the resin is analyzed for iodine–131 (*11*, *13*). The resin effluent is analyzed and the resulting spectral data is resolved by the application of a matrix method of analysis (*12*).

The analytical procedure for determining strontium–89 and strontium–90 concentrations employs an ion-exchange system similar to that developed by Porter, et al (*6*).

The radionuclide concentration of strontium–90 and cesium–137 are shown in table 8 for

Table 8. Radionuclide concentrations in New York pasteurized milk, April–July 1968

Sampling location	Date	Radionuclide concentrations (pCi/liter)	
		Strontium-90	Cesium-137
Albany	April	7	ND
	May	10	ND
	June	7	ND
	July	9	21
Buffalo	April	7	ND
	May	5	ND
	June	8	ND
	July	4	ND
Massena	April	8	25
	May	10	25
	June	10	33
	July	18	31
Newburgh	April	7	ND
	May	12	ND
	June	NS	NS
	July	12	ND
New York City	April	9	22
	May	11	23
	June	14	26
	July	12	24
Syracuse	April	7	ND
	May	8	ND
	June	NS	NS
	July	NA	ND

ND, nondetectable.
NS, no sample.
NA, no analysis.

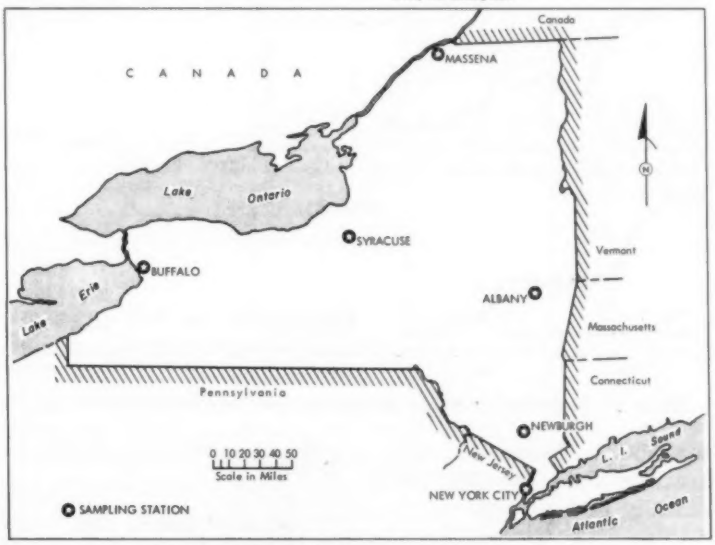

Figure 16. New York milk sampling stations

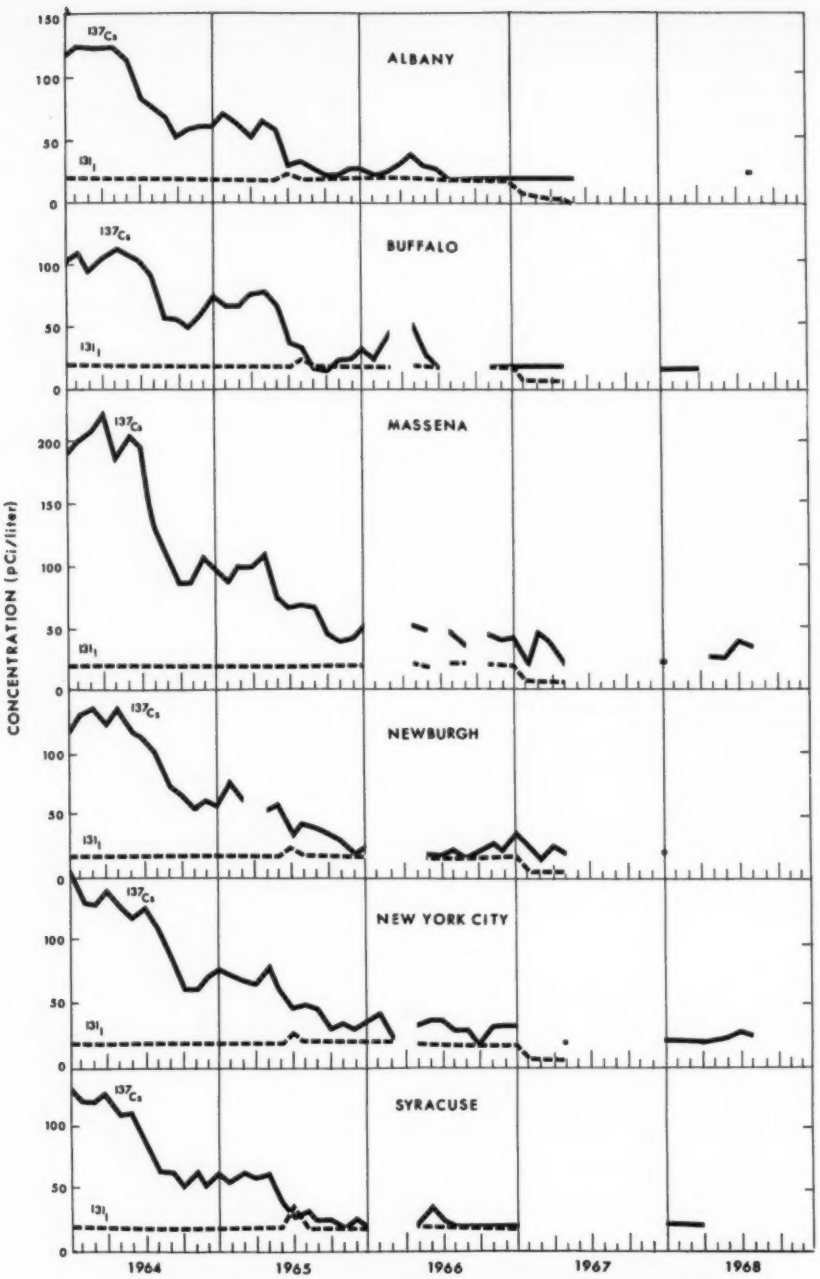

Figure 17. Radionuclide concentrations in New York milk, 1964–July 1968

April through July 1968. Cesium–137 and iodine–131 concentrations since January 1964 are presented graphically in figure 17.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
October–December 1967	May 1968
January–March 1968	August 1968

10. Oregon Milk Network April–July 1968

Division of Sanitation and Engineering
Oregon State Board of Health

The Oregon State Board of Health has monitored radionuclide concentrations in milk since March 1962. As part of this program routine milk samples are collected at seven major production areas (figure 18), which supply 90 percent of the milk distributed in Oregon. Currently, pasteurized milk samples are collected monthly by the Oregon Department of Agriculture, except in the Portland area where weekly samples are collected by the city of Portland. The milk sampling frequency is accelerated to a weekly basis in areas where iodine–131 concentrations exceed 100 pCi/liter, or when cesium–137 concentrations exceed 500 pCi/liter. Strontium–90 analyses are performed on a bimonthly basis, but may be done monthly when significant increases are observed.

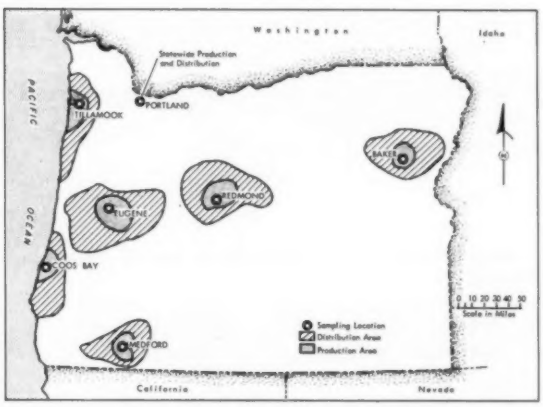

Figure 18. Oregon milk production and distribution areas

Strontium–90 concentrations are determined using a trichloracetic acid analytical procedure (*15*). Iodine–131, cesium–137, and barium–140 concentrations are determined by gamma-ray scintillation spectrometry (*16*).

Table 9 gives the strontium–90 and cesium–137 concentrations in pasteurized milk from April through July 1968. These data are presented graphically in figure 19. Iodine–131 and barium–140 concentrations remained below minimum detectable levels of 15 pCi/liter for all samples which were collected in April through July 1968.

Table 9. Radionuclide concentrations in Oregon pasteurized milk, April–July 1968

Location	Sampling frequency [a]	Strontium-90 (pCi/liter)				Cesium-137 (pCi/liter)			
		Apr	May	June	July	Apr	May	June	July
Baker	M	NA	NA	NA	3	<15	<15	<15	<15
Coos Bay	M	NA	20	NA	16	<15	16	26	15
Eugene	M	NA	4	NA	4	21	<15	15	15
Medford	M	NA	4	NA	2	<15	<15	17	<15
Portland composite	W	NA	NA	NA	8	17	23	18	20
Portland local	W	NA	NA	NA	7	17	28	21	18
Redmond	M	NA	NA	NA	4	<15	17	<15	<15
Tillamook	M	NA	NA	NA	NA	18	56	42	20

[a] M, sampled monthly.
W, sampled weekly.
NA, no analysis.

Figure 19. Radionuclide concentrations in Oregon milk network, 1964–July 1968

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
October–December 1967	June 1968
January–March 1968	September 1968

11. Pennsylvania Milk Network April–July 1968

Bureau of Environmental Health
Pennsylvania Department of Health

Samples of pasteurized milk are routinely collected from four major milk consumption areas throughout Pennsylvania (figure 20).

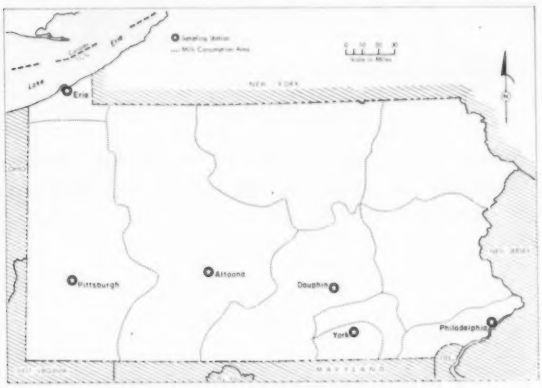

Figure 20. Pennsylvania pasteurized milk network sampling stations

Samples are collected weekly in Pittsburgh, while biweekly composite samples are now collected from the other three stations. At each sampling location, sub-samples are collected from the major dairies supplying the area and are composited in proportion to the amount of milk processed by each dairy. This composite is then sent to the Radiation Laboratory of the Division of Occupational Health in Harrisburg where the samples are analyzed for iodine–131, potassium–40, and cesium–137 and then composited for a monthly analysis of strontium–90. Stronium–90 analyses have been carried out since April 1963.

The monthly average potassium–40, strontium–90, iodine–131, and cesium–137 concentrations in pasteurized milk are given in table 10. For comparative purposes, strontium–90, iodine–131, and cesium–137 concentrations are presented graphically in figure 21.

The chemical separation technique for strontium–90 is essentially an ion-exchange method described by Porter, et al (*17*).

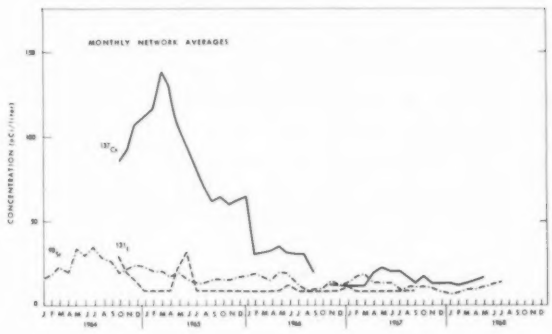

Figure 21. Radionuclide concentrations in Pennsylvania milk, 1964–July 1968

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
October–December 1967	May 1968
January–March 1968	August 1968

Table 10. Radionuclide concentrations in Pennsylvania pasteurized milk April–July 1968

Sampling location	Potassium (g/liter)				Strontium-90 (pCi/liter)				Cesium-137 (pCi/liter)			
	April	May	June [b]	July [c]	April	May	June	July	April	May	June [b]	July [c]
Altoona [a]	1.6	NS	NS	NS	9	NS	NS	NS	9	NS	NS	NS
Dauphin	1.4	1.6	NA	1.6	5	10	10	4	21	12	NA	23
Erie	1.7	1.7	NA	1.5	14	12	16	16	22	18	NA	49
Philadelphia	1.5	1.5	NA	1.6	10	11	11	15	13	17	NA	28
Pittsburgh	1.6	1.5	NA	1.7	14	11	12	16	13	17	NA	26
York [a]	1.6	NS	NS	NS	10	NS	NS	NS	8	NS	NS	NS

[a] Sampling discontinued after April.
[b] Gamma analysis for June is missing due to analyzer malfunction.
[c] Gamma results for July are in doubt due to need for recalibration following June breakdown.
NS, no smple.
NA, nao analysis.

12. Tennessee Milk Network July 1968

Division of Preventable Diseases
Department of Public Health
State of Tennessee

The Tennessee Department of Public Health began sampling pasteurized milk for radionuclide analysis in July of 1965. Currently the Department is collecting semimonthly milk samples from four cities (figure 22). In order to obtain a representative sample of the milk consumed in the areas monitored, a sample of milk is collected from each milk distributor supplying the city. The samples from the individual distributors are then composited in proportion to the contribution each makes to the total city milk supply.

Analytical procedures

The semimonthly milk samples from each city sampled are analyzed by gamma-ray scintillation spectrometry for potassium–40, iodine–131, cesium–137, and barium–140, using a 3½-liter sample (*14*). After gamma-ray analysis, strontium–89, strontium–90, and barium–140 concentrations are determined radiochemically using ion-exchange procedures (*15*). Chemical analyses are also made for stable calcium and potassium.

The Chattanooga milk sample is monitored by both the State and the Public Health Service's Southeastern Radiological Health Laboratory. This dual examination of aliquot samples provides a crosscheck between the two laboratories.

Results

The monthly average stable element and radionuclide concentrations in Tennessee pasteurized milk are presented in table 11 for July 1968.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
January–March 1968	July 1968
April–June 1968	October 1968

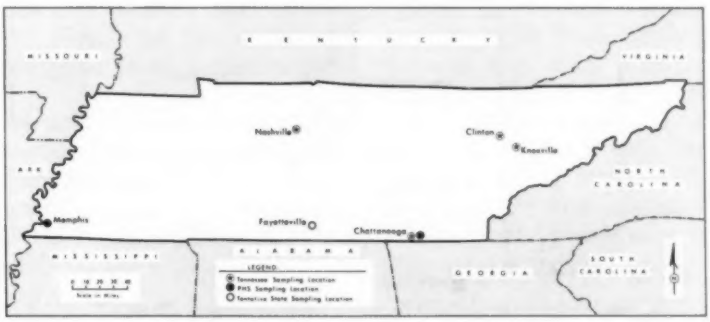

Figure 22. Tennessee pasteurized milk sampling areas

Table 11. Radionuclides in Tennessee pasteurized milk July 1968

Location	Concentration (g/liter)	Radionuclide concentration (pCi/liter)				
	Potassium	Strontium-89	Strontium-90	Iodine-131	Cesium-137	Barium-140
Chattanooga	1.5	32	5	<9	24	<8
Clinton	1.6	13	13	<9	19	<8
Knoxville	1.6	10	7	<9	20	<8
Nashville	1.6	8	6	<9	25	<8

13. Texas Milk Network July 1968

Texas State Department of Health[1]

The Texas State Department of Health initiated a statewide milk sampling network for radionuclide content in April 1964. At present, samples of raw milk are collected from each of twelve sampling points once each calendar quarter. The station locations shown in figure 23 were chosen to give maximum geographical and population coverage.

Samples are routinely analyzed for strontium–90 by a chemical separation technique employing ion exchange columns (*17*). Prepared samples are counted for 100 minutes in a low-background beta-particle counter.

Potassium–40, iodine–131, barium–140 and cesium–137 concentrations are determined by gamma-ray spectrometry. The procedure employs a 4- by 4-inch sodium iodide crystal and a 400-channel analyzer. Samples are counted for 100 minutes in a 3.5 liter Marinelli beaker. The matrix method of calculation is used and detection limits at the 95-percent confidence level are 10 pCi/liter.

[1]Acknowledgement is accorded to the staff of the Radiation Control Program, Division of Occupational Health and Radiation Control, under the direction of Mr. Martin C. Wukasch, chief engineer.

Table 12. Stable element and radionuclide concentrations in Texas raw milk network, July 1968 [a]

Sampling location	Potassium (g/liter)	Radionuclide concentrations (pCi/liter)	
		Strontium-90	Cesium-137
	July	July	July
Amarillo	NA	NA	NA
Corpus Christi	NA	NA	NA
El Paso	NA	NA	NA
Fort Worth	1.4	8	10
Harlingen	NA	NA	NA
Houston	1.5	14	15
Lubbock	NA	NA	NA
Midland	1.5	5	(b)
San Antonio	NA	NA	NA
Texarkana	NA	NA	NA
Uvalde	1.2	NA	(b)
Wichita Falls	NA	NA	NA

[a] Samples collected on a quarterly frequency at each sampling location.
[b] Below detectable limits.
NA, no analysis.

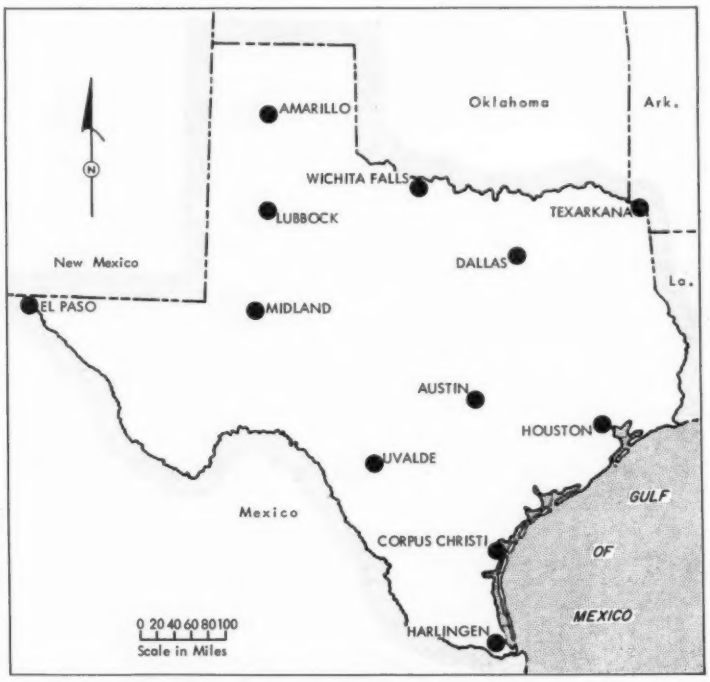

Figure 23. Texas milk sampling stations

Results

Potassium–40, strontium–90 and cesium–137 results by station and month for July 1968 are presented in table 12. During this time, iodine–131 and barium–140 concentrations were below their limits of detectability (10 pCi/liter).

Comparison of the observed radionuclide concentrations with the Federal Radiation Council guides for peacetime operation indicates that at no time during the period of surveillance did the radionuclide concentrations in Texas milk approach levels suggesting any remedial action (*10*).

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
January–March 1968	July 1968
April–June 1968	October 1968

14. Washington Milk Network April–July 1968

Office of Air Quality Control
State of Washington Department of Health

The Washington State Department of Health initiated a surveillance program for radioactivity in raw milk in December 1962. The collection points shown in figure 24 were selected to provide samples representative of varying climatological conditions within the State's two major milksheds. In addition to the eight milk sampling locations in Washington, milk is sampled from Northwest Idaho (Sandpoint), as this area forms a part of the Spokane milkshed. Details of the sampling procedures were presented in an earlier report (*18*).

Selected samples are radiochemically analyzed for strontium–90. Potassium–40, iodine–131, cesium–137, and barium–140 concentrations are determined by gamma-ray scintillation spectrometry. Details of the analytical procedures were presented earlier (*17*).

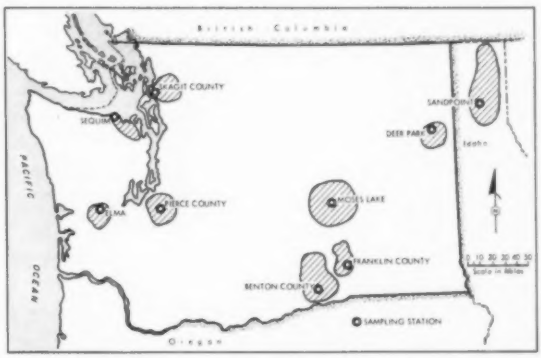

Figure 24. Washington milksheds and sampling locations

Table 13 presents monthly radionuclide concentrations in Washington raw milk for April through July 1968. Samples collected during April through July 1968 contained less than 10 pCi/liter of iodine–131. Barium–140 results remained below 15 pCi/liter for all samples collected during this period. Monthly average strontium–90 and cesium–137 concentrations are presented graphically in figure 25 to display general trends.

Table 13. Stable element and radionuclide concentrations in Washington raw milk, April–July 1968

Sampling location	Potassium (g/liter)				Radionuclide concentrations (pCi/liter)							
					Strontium-90				Cesium-137			
	April	May	June	July	April	May	June	July	April	May	June	July
Benton County	NS	1.7	NS	1.5	NS	<1	NS	1	NS	<15	NS	<15
Deer Park	1.6	1.6	1.6	1.4	5	3	5	2	<15	<15	<15	21
Elma	1.7	1.6	1.5	1.5	2	8	10	4	<15	47	35	16
Franklin County	1.6	NS	1.5	NS	1	NS	1	NS	<15	NS	<15	NS
Moses Lake	1.7	1.6	1.5	1.5	2	1	2	<1	<15	<15	<15	<15
Pierce County	1.6	1.7	1.5	1.6	1	5	6	6	<15	19	<15	24
Sandpoint, Idaho	1.5	1.6	1.6	1.4	7	—	10	8	22	18	30	30
Skagit County	1.4	1.5	1.6	1.5	8	2	5	2	26	30	24	18

NS, no sample.

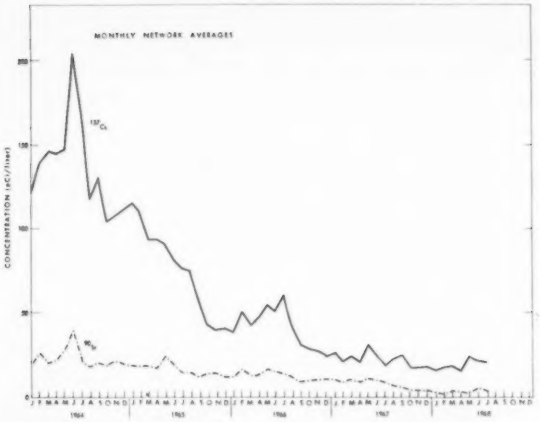

Figure 25. Radionuclide concentrations in Washington milk, 1963–July 1968

During this reporting period, four samples (two from Benton County and two from Franklin County) were analyzed for zinc–65. Results ranged from <20 pCi/liter to 47 pCi/liter of zinc–65. Milk samples produced in areas using Columbia River water for irrigation have periodically been found to contain this radionuclide.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
October–December 1967	June 1968
January–March 1968	September 1968

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(*4*) PORTER, C., D. CAHILL, R. SCHNEIDER, P. ROBBINS, W. PERRY, and B. KAHN. Improved determination of strontium–90 in milk by ion-exchange method. Anal Chem 33:1306–1309 (September 1961).

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(*16*) OREGON STATE BOARD OF HEALTH, DIVISION OF SANTITATION AND ENGINEERING. Oregon milk network, April–June 1965. Radiol Health Data 6:683–684 (December 1965).

(*17*) PORTER, C. D., R. SCHNEIDER, P. ROBBINS, W. PERRY, and B. KAHN. Improved determinations of strontium–90 in milk by an ion exchange method. Anal Chem 36:676–678 (March 1964).

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Food and Diet Surveillance

Efforts are being made by various Federal and State agencies to estimate the dietary intake of selected radionuclides on a continuing basis. These estimates along with the guidance developed by the Federal Radiation Council, provide a basis for evaluating the significance of radioactivity in foods and diet.

Networks presently in operation and reported routinely include those listed below. These networks provide data useful for developing estimates of nationwide dietary intakes of radionuclides. Programs most recently reported in *Radiological Health Data and Reports* and not covered in this issue are as follows:

Programs	Period reported	Last presented
California Diet Study	July-October 1967	May 1968
Institutional Diet, PHS	January-March 1968	October 1968
Tri-City Diet, HASL	April-December 1967	June 1968

1. Estimated Daily Intake of Radionuclides in Connecticut Standard Diet, January–June 1968

Connecticut State Department of Health

The Connecticut State Department of Health has been analyzing a standard diet on a monthly basis since March 1963. Analyses are made for strontium–89, strontium–90, and gamma-ray emitters.

The standard diet was selected to represent the food intake of an 18-year-old boy for 1 day (table 1). The total weight of the complete blended diet, averaging 3 kilograms, included milk and dairy products. When raw fruit or vegetables were sampled, they were washed before blending.

Cesium–137 concentrations were determined by gamma-ray spectrometry (*1*). Strontium–89 and strontium–90 concentrations were determined by chemical separation techniques (*1*).

Table 2 presents the analytical results for the Connecticut standard diet from January through June 1968. Results representative of the total daily intake for the radionuclides observed are presented in table 3.

In order to evaluate general trends, the strontium–90 and cesium–137 daily intakes are plotted as a function of time in figures 1 and 2.

Table 1. Foods included in standard diet

Bread, white—8 slices	Ice cream—½ pint
Butter, ½ stick	Lettuce, washed—4-5 leaves
Carrots, scraped—½ cup	Milk—3 cups
Celery, washed and trimmed—3 stalks	Oatmeal—uncooked—43 grams
Cookies—4	Orange—1
Cottage cheese—⅔ cup	Peanut butter—2½ tablespoons
Cupcakes—2	Pears, canned—2 halves with juice
Egg—1	Potatoes, washed, not peeled—2
Green beans, washed—½ cup	Sugar—5 tablespoons
Ham—85 grams	Tomato juice—113 grams
Hamburger—227 grams	Tuna fish, drained—43 grams

Table 2. Radionuclide concentrations in Connecticut standard diet,[a] January–June 1968

Month (1968)	Potassium (g/kg)	Strontium-90 (pCi/kg)	Cesium-137 (pCi/kg)
January	2.3	7	10
February	2.1	7	10
March	2.0	8	<10
April	2.0	8	20
May	NA	NA	NA
June	2.4	10	20

[a] All strontium-89 values were <3 for this period.

Table 3. Daily radionuclide intakes in Connecticut standard diet,[a] January–June 1968

Month (1968)	Potassium (g/day)	Strontium-90 (pCi/day)	Cesium-137 (pCi/day)
January	7.2	21	30
February	6.6	23	40
March	6.3	24	20
April	6.1	23	60
May	NA	NA	NA
June	7.7	31	70

[a] All strontium-89 values were <3 for this period.

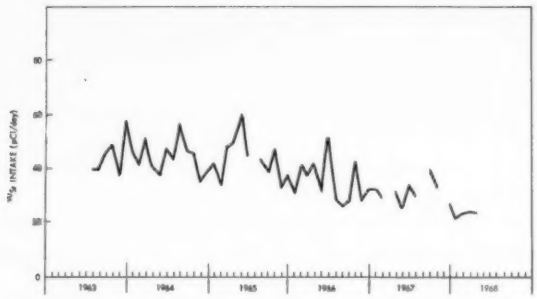

Figure 1. Strontium–90 intake in Connecticut standard diet, 1963–July 1968

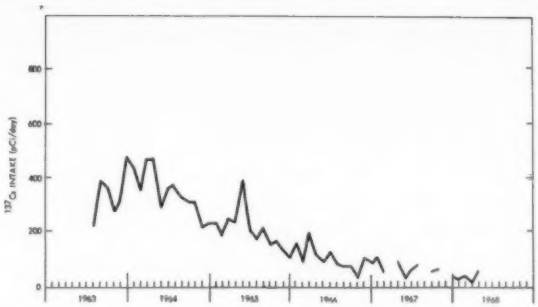

Figure 2. Cesium–137 intake in Connecticut standard diet, 1963–July 1968

REFERENCE

(1) CONNECTICUT STATE DEPARTMENT OF HEALTH. Estimated daily intake of radionuclides in Connecticut standard diet, March 1963–December 1964. Radiol Health Data 6:381–382 (July 1965).

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
January–June 1967	November 1967
July–December 1967	May 1968

SECTION II. WATER

The Public Health Service, the Federal Water Pollution Control Administration and other Federal, State, and local agencies operate extensive water quality sampling and analysis programs for surface, ground, and treated water. Most of these programs include determinations of gross beta and gross alpha radioactivity and specific radionuclides.

Although the determination of the total radionuclide intake from all sources is of primary importance, a measure of the public health importance of radioactivity levels in water can be obtained by comparison of the observed values with the Public Health Service Drinking Water Standards (*1*). These standards, based on consideration of Federal Radiation Council (FRC) recommendations (*2–4*), set the limits for approval of a drinking water supply containing radium–226 and strontium–90 as 3 pCi/liter and 10 pCi/liter, respectively. Limits may be set higher if the total intake of radioactivity from all sources remains within the guides recommended by FRC for control action. In the known absence[1] of strontium–90 and alpha-particle emitters, the limit is 1,000 pCi/liter gross beta radioactivity, except when additional analysis indicates that concentrations of radionuclides are not likely to cause exposures greater than the limits indicated by the Radiation Protection Guides. Surveillance data from a number of Federal and State programs are published periodically to show current and long-range trends. Water sampling activities recently reported in *Radiological Health Data and Reports* are listed below.

[1]Absence is taken to mean a negligibly small fraction of the specific limits of 3 pCi/liter and 10 pCi/liter for unidentified alpha-particle emitters and strontium–90, respectively.. The limit for unidentified alpha emitters is taken as the limit for radium–226.

Water sampling program	Period reported	Last presented
Colorado River Basin	1965–1966	May 1968
Florida	1965–1966	July 1968
Minnesota	July–December 1967	October 1968
New York	June–December 1967	October 1968
Radiostrontium in Tap Water, HASL	July–December 1967	June 1968
Tritium in Surface Water, PHS	1967	October 1968
Washington	July 1966–June 1967	August 1968

REFERENCES

(*1*) U. S. PUBLIC HEALTH SERVICE. Drinking water standards, revised 1962, PHS Publication No. 956. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (March 1963).

(*2*) FEDERAL RADIATION COUNCIL. Radiation Protection Guidance for Federal Agencies. Memorandum for the President, September 1961. Reprint from the Federal Register of September 26, 1961.

(*3*) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 1. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (May 1960).

(*4*) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 2. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (September 1961).

Gross Radioactivity, May 1968, and Strontium-90, July 1966-September 1967, in Surface Waters of the United States

Division of Pollution Surveillance
Federal Water Pollution Control Administration
Department of the Interior

The monitoring of levels of radioactivity in surface waters of the United States was begun in 1957 as part of the Water Pollution Surveillance System currently operated by the Federal Water Pollution Control Administration. Beginning with the establishment of 50 sampling points, this system has been expanded to include 131 stations. These stations are operated jointly with other Federal, State, and local agencies, and with private industries. Samples are taken from surface waters of all major U.S. river basins for physical, chemical, biological, and radiological analyses. The system provides background information necessary for recognizing water quality trends and for determining current and general levels of surface water contamination and early detection of specific situations which may warrant more detailed evaluation. Complete data and exact sampling locations for 1958 through 1963 are published in annual compilations (*1–6*). Data for subsequent years are available on request.

Sampling procedures

The participating agencies collect 1-liter "grab" samples each week and ship them to the Surveillance System Laboratory in Cincinnati. Presently, gross alpha and beta radioactivity determinations are made either on monthly composites of the weekly samples or on each weekly sample. Weekly alpha and beta radio-

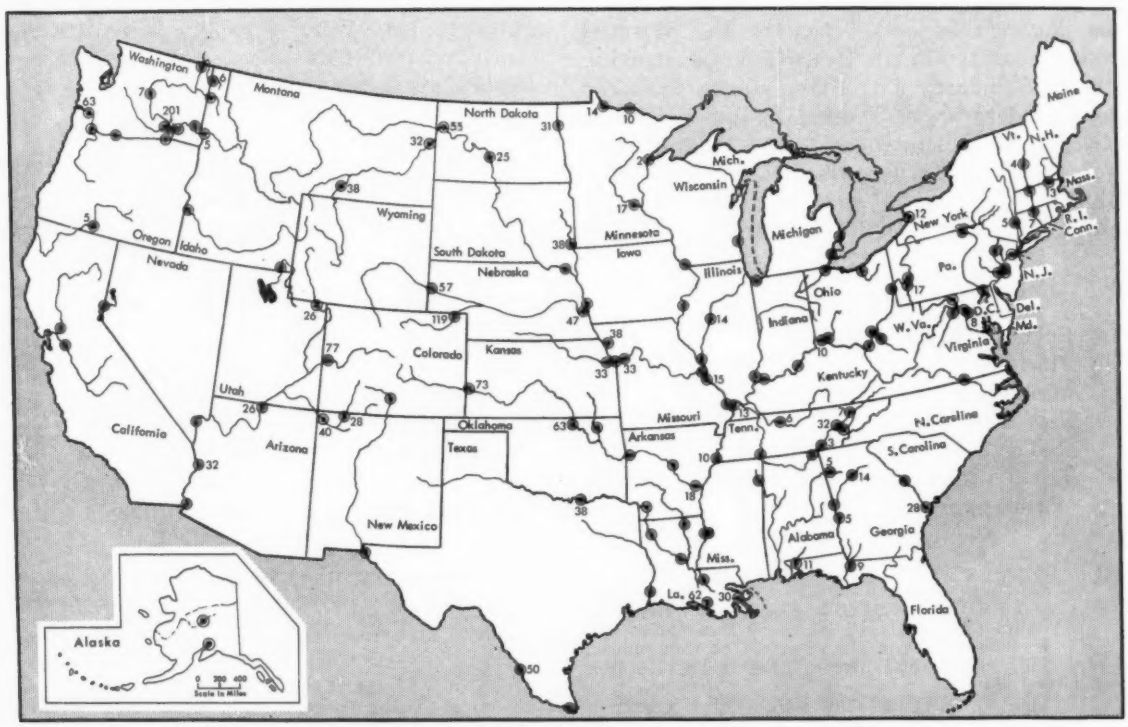

Figure 1. Sampling locations and associated total beta radioactivity (pCi/liter) in surface waters, May 1968

activity determinations are scheduled for stations located downstream from known potential sources of radioactive waste. Weekly analyses are conducted at all newly established stations for the first year of operation. Weekly analyses are also scheduled for selected stations in an effort to detect short-term increases in radioactivity from current or recent nuclear tests or events.

Analytical methods

The analytical method used for determining gross alpha and beta radioactivity is described in the twelfth edition of "Standard Methods for the Examination of Water and Wastewater" (*7*). Suspended and dissolved solids are separated by passing the sample through a membrane filter (type HA) with a pore size of 0.45 micron. Planchets are then prepared for counting the dissolved solids (in the filtrate) and the suspended solids (on the charred membrane filter) in an internal proportional counter. Reference sources of U_3O_8 are used for daily checking of the counter.

Normally, samples are counted within 2 weeks following collection or within 1 week after compositing. The decay of radioactivity is followed on each sample for which the first analysis shows unusually high radioactivity. Also, if a recount indicates that the original analysis was questionable, values based on the recount are recorded. All results are reported for the time of counting and are not extrapolated to the date of collection.

Results

Table 1 presents the current preliminary results of the alpha-and beta-particle analysis of United States surface waters. The stations on a river are arranged in the table according to their distance from the headwaters. The figures for gross alpha and gross beta radioactivity represent either determinations on composite samples or means of weekly determinations where composites were not made. The monthly means are reported to the nearest pCi/liter. When all samples have 0 pCi/liter, the mean is reported as 0; when the calculated mean in between 0 and 0.5, the mean is reported as <1 pCi/liter.

A geographical perspective of the radioactivity in surface water is obtained from the numbers printed near the stations shown in figure 1, which gives the average total beta radioactivity in suspended-plus-dissolved solids in raw water collected at each station.

It has been observed that, in water, the natural environmental beta radioactivity is usually several times that of the natural environmental alpha radioactivity. Nuclear installations may contribute additional alpha or beta radioactivity whereas fallout contributes primarily additional beta radioactivity. The radioactivity associated with dissolved solids provides a rough indication of the levels which would occur in treated water, since nearly all suspended matter is removed by treatment processes (*9*).

Special note is taken when the alpha radioactivity is 15 pCi/liter or greater or when the beta radioactivity is 150 pCi/liter or greater. These arbitrary levels provide a basis for the selection of certain data and for comment on the data, if needed. They reflect no public health significance as the Public Health Service drinking water standards have already provided the basis for this assessment (*10*). Changes from or toward these arbitrary levels are also noted in terms of changes in radioactivity per unit weight of solids. No discussion of gross radioactivity per gram of dissolved or suspended solids for all stations of the Water Pollution Surveillance System will be attempted at this time. Comments are made only on monthly average values. Occasional high values from single weekly samples may be absorbed into a relatively low average. When these values are significantly high comment will be made.

During May 1968, the following stations showed values of 15 pCi/liter or greater on alpha radioactivity for dissolved solids:

> Arkansas River, Coolidge Kans, Colorado River, Parker Dam, Ariz-Calif; North Platte River, Henry, Nebr; and South Platte River, Julesburg, Colo.

Strontium–90 determinations and results

Beginning in 1959, strontium–90 analyses of the total solids in surface waters were made quarterly on 3-month composites of aliquots from weekly samples. Beginning in November

Table 1. Radioactivity in raw surface waters, May 1968

Station	Average alpha radioactivity (pCi/liter)			Average beta radioactivity (pCi/liter)		
	Suspended	Dissolved	Total	Suspended	Dissolved	Total
Animas River:						
Cedar Hill, N. Mex.	6	1	7	22	6	28
Apalachicola River:						
Chattahoochee, Fla.	1	0	1	5	4	9
Arkansas River:						
Coolidge, Kans.	1	26	27	6	67	73
Ponca City, Okla.	5	0	5	38	25	63
Pendleton Ferry, Ark.	0	0	0	4	14	18
Atchafalaya River:						
Morgan City, La.	10	0	10	54	8	62
Big Horn River:						
Hardin, Mont.	2	5	7	9	29	38
Big Sioux River:						
Sioux Falls, S. Dak.	1	3	4	7	31	38
Chattahoochee River:						
Atlanta, Ga.	2	0	2	9	5	14
Columbus, Ga.	1	0	1	3	2	5
Clearwater River:						
Lewiston, Idaho	0	0	0	3	2	5
Clinch River:						
Clinton, Tenn.	0	0	0	3	4	7
Kingston, Tenn.[a]	1	0	1	2	30	32
Colorado River:						
Loma, Colo.	12	5	17	59	18	77
Page, Ariz.	0	6	6	1	25	26
Parker Dam, Calif.-Ariz.	0	15	15	2	30	32
Columbia River:						
Wenatchee, Wash.	0	1	1	1	6	7
Pasco, Wash.[a]	0	1	1	69	132	201
Clatskanie, Ore.	0	0	0	17	46	63
Connecticut River:						
Wilder, Vt.	0	0	0	0	4	4
Enfield Dam, Conn.	0	0	0	3	4	7
Coosa River:						
Rome, Ga.	1	0	1	1	4	5
Cumberland River:						
Cheatham Lock, Tenn.	0	0	0	4	2	6
Escambia River:						
Century, Fla.	1	0	1	5	6	11
Great Lakes:						
Duluth, Minn.	0	0	0	0	2	2
Buffalo, N.Y.	0	0	0	1	11	12
Green River:						
Dutch John, Utah	0	3	3	2	24	26
Hudson River:						
Poughkeepsie, N.Y.	0	0	0	1	4	5
Illinois River:						
Peoria, Ill.	1	1	2	1	13	14
Kansas River:						
DeSoto, Kans.	2	3	5	8	25	33
Klamath River:						
Keno, Ore.	0	0	0	1	4	5
Merrimack River:						
Lowell, Mass.	0	0	0	4	9	13
Mississippi River:						
St. Paul, Minn.	0	0	0	2	15	17
E. St. Louis, Ill.	2	1	3	9	6	15
W. Memphis, Ark.	1	1	2	4	6	10
New Orleans, La.	6	0	6	20	10	30
Missouri River:						
Williston, N. Dak.	5	3	8	27	28	55
Bismarck, N. Dak.	0	3	3	3	22	25
St. Joseph, Mo.	3	2	5	10	28	38
Missouri City, Mo.	1	3	4	2	31	33
Monongahela River:						
Pittsburgh, Pa.	2	0	2	8	9	17
North Platte River:						
Henry, Nebr.	3	15	18	10	47	57
Ohio River:						
Cincinnati, Ohio	1	0	1	3	7	10
Cairo, Ill.	3	0	3	5	8	13
Pend Oreille River:						
Albeni Falls Dam, Idaho	0	0	0	1	5	6
Platte River:						
Plattsmouth, Nebr.	2	4	6	16	31	47
Potomac River:						
Washington, D.C.	1	0	1	3	5	8
Rainy River:						
International Falls, Minn.	0	0	0	2	8	10
Baudette, Minn.	0	0	0	2	12	14
Red River, North:						
Grand Forks, N. Dak.	1	2	3	2	29	31
Red River, South:						
Denison, Tex.	0	1	1	0	38	38
Rio Grande:						
Laredo, Tex.	7	1	8	32	18	50
San Juan River:						
Shiprock, N. Mex.	7	1	8	30	10	40
Savannah River:						
Port Wentworth, Ga.[a]	0	0	0	6	22	28
South Platte River:						
Julesburg, Colo.	4	27	31	11	108	119
Tennessee River:						
Chattanooga, Tenn.	0	2	2	0	3	3
Yellowstone River:						
Sidney, Mont.	2	3	5	15	17	32
Maximum	12	27	31	69	132	201
Minimum	0	0	0	0	2	2

[a] Gross beta radioactivity at this station may not be directly comparable to gross beta radioactivity at other stations because of the possible contribution of radionuclides from an upstream nuclear facility in addition to the contribution from fallout and naturally occurring radionuclides.

1962, the frequency of analysis was reduced to two quarterly samples per year at each sampling point except at those stations immediately below nuclear installations, where regular quarterly analyses were continued. The method used for determining strontium–90 is a modification of a procedure described by Harley (*8*). Yttrium–90 together with a yttrium carrier is precipitated as yttrium oxalate and the latter is washed, dried, weighted, and counted in a low-background, anticoincidence, end-window proportional counter.

Table 2 presents the results of quarterly analyses of strontium–90 concentrations in U.S. surface waters for the third and fourth quarters of 1966 and the first, second and third quarters of 1967. The stations are arranged in the table according to their distance from the headwaters.

While there are no standards for strontium–90 radioactivity of total solids in surface waters, the Public Health Service Drinking Water Standards set the limit for strontium–90 concentrations in drinking water at 10 pCi/liter.

Table 2. Quarterly strontium-90 concentrations in surface waters, July–December 1966 and January–September 1967

Station	Average concentrations (pCi/liter)				
	July-Sept 1966	Oct-Dec 1966	Jan-Mar 1967	Apr-June 1967	July-Sept 1967
Allegheny River:					
Pittsburgh, Pa.			0.8		1.2
Animas River:					
Cedar Hill, N. Mex.	1.4	2.0		1.1	1.0
Apalachicola River:					
Chattahoochee, Fla.	1.1	1.5		0.8	
Arkansas River:					
Coolidge, Kans.	3.6	4.3		3.2	6.1
Ponca City, Okla.			1.1		2.7
Fort Smith, Ark.	2.8	3.7		3.0	2.4
Little Rock, Ark.					2.4
Pendleton Ferry, Ark.					1.7
Atchafalaya River:					
Morgan City, La.	2.7	3.6		2.0	
Bear River:					
Preston, Idaho	2.2	1.0	1.1	1.1	
Big Horn River:					
Hardin, Mont.					1.6
Big Sioux River:					
Sioux Falls, S. Dak.	3.2	2.4		3.3	2.7
Brazos River:					
Arcola, Tex.				2.6	3.2
Chattahoochee River:					
Atlanta, Ga.					1.3
Columbus, Ga.			0.7		1.4
Lanett, Ala.	1.4	1.4		0.9	
Chena River:					
Fairbanks, Alaska			1.0		
Clearwater River:					
Lewiston, Idaho	0.7	0.6		0.5	
Clinch River:					
Clinton, Tenn.	0.9	0.9	0.7		0.5
Kingston, Tenn.	3.6	2.3		5.1	2.2
Colorado River:					
Loma, Colo.			0.8		1.8
Page, Ariz.	3.0	5.8		3.8	
Boulder City, Nev.			2.9		3.0
Parker Dam, Calif/ Ariz.	4.0	2.6		4.5	
Yuma, Ariz.		2.5			2.3
Columbia River:					
Northport, Wash.	1.5	1.4		0.8	
Wenatchee, Wash.			1.0		2.5
Pasco, Wash.		1.8	1.4		2.0
McNary Dam, Ore.	1.3	1.4	1.0		1.8
Bonneville, Ore.	1.7	1.9		1.9	
Clatskanie, Ore.					0.6
Connecticut River:					
Wilder, Vt.	1.5	1.2		1.0	
Northfield, Mass.				0.8	1.1
Enfield Dam, Conn.	1.3	2.6			1.0
Coosa River:					
Rome, Ga.			1.0		0.7
Cumberland River:					
Cheatham Lock, Tenn.	2.1			0.8	
Cuyahoga River:					
Cleveland, Ohio	4.5	1.2		2.0	
Delaware River:					
Martins Creek, Pa.			0.9		0.9
Trenton, N.J.	1.1	1.2		0.9	
Philadelphia, Pa.			1.1		0.9
Escambia River:					
Century, Fla.			0.9		1.0
Great Lakes:					
Duluth, Minn.					0.9
Saulte Ste. Marie, Mich.	1.1			0.9	
Milwaukee, Wis.			1.0		1.4
Gary, Ind.	1.6	1.9		1.6	
Port Huron, Mich.		2.1	1.3		1.4
Gibraltar, Mich.					1.3
Detroit, Mich.	1.6	2.2		1.6	
Buffalo, N.Y.			2.1		3.3
Green River:					
Dutch John, Utah	4.3	4.4		3.4	
Hudson River:					
Poughkeepsie, N.Y.			1.2		1.7
Illinois River:					
Peoria, Ill.		1.7	0.9		1.5
Grafton, Ill.	1.6		1.0		1.4
Kanawha River:					
Winfield Dam, W. Va.	1.0	1.0		0.6	
Kansas River:					
DeSoto, Kans.			2.1		3.0
Klamath River:					
Keno, Ore.			1.3		1.0
Little Miami River:					
Cincinnati, Ohio	1.6	1.8		1.3	
Maumee River:					
Toledo, Ohio			1.3		1.6
Merrimack River:					
Lowell, Mass.	2.0	2.2	1.8		1.6
Mississippi River:					
St. Paul, Minn.	4.5			3.3	
Dubuque, Iowa			2.6		3.1
Burlington, Iowa	3.2	2.9		2.0	
E. St. Louis, Ill.			1.6		2.1
Cape Girardeau, Mo.		3.4		2.3	
W. Memphis, Ark.			1.1		1.9
Vicksburg, Miss.	2.0	2.6	1.7	2.6	
Delta, La.					2.2
New Roads, La.			0.9	0.9	
New Orleans, La.	2.5	2.3		1.4	
Missouri River:					
Williston, N. Dak.			2.2		2.6
Bismarck, N. Dak.	2.9	3.3		2.5	
Yankton, S. Dak.			2.5		3.1
Omaha, Nebr.	3.6	5.0	2.1	3.7	
St. Joseph, Mo.					3.2
Kansas City, Kans.	4.5	4.2	2.1	3.1	
Missouri City, Mo.					3.0
St. Louis, Mo.	3.9	3.5		2.4	
Monongahela River:					
Pittsburgh, Pa.			1.1		1.5
North Platte River:					
Henry, Nebr.			0.5		2.4
Ohio River:					
Toronto, Ohio			2.9		
Addison, Ohio	1.8	2.2		1.5	
Huntington, W. Va.			1.1		1.4
Cincinnati, Ohio	2.0	1.2		1.2	
Louisville, Ky.			1.5		1.0
Evansville, Ind.	1.5	2.1		1.3	
Cairo, Ill.			1.1		1.8
Ouachita River:					
Bastrop, La.	2.6	2.5		2.0	
Pend Oreille River:					
Albeni Falls Dam, Idaho			1.2		
Platte River:					
Plattsmouth, Nebr.	2.8	2.4		2.6	
Potomac River:					
Williamsport, Md.			0.4		0.9
Great Falls, Md.	1.1	2.3		1.1	
Washington, D.C.	1.4	1.3		0.6	
Rainy River:					
Baudette, Minn.			1.2		4.1
International Falls, Minn.			3.8		3.0
Red River, North:					
Grand Forks, N. Dak.	8.6		3.7	4.1	4.5
Red River, South:					
Denison, Tex.	6.7	3.7	3.9		4.1
Index, Ark.				2.8	
Bossier City, La.		2.5	1.1	1.2	2.8
Alexandria, La.			2.6		3.4
Rio Grande:					
Alamosa, Colo.			1.3		0.6
El Paso, Tex.	3.3	0.4		0.2	
Laredo, Tex.			0.6		6.0
Brownsville, Tex.		0.4	1.6		
Roanoke River:					
John H. Kerr Reservoir/ Dam, Va.			0.4		1.3
Sabine River:					
Ruliff, Tex.	3.1		1.9		
Sacramento River:					
Greens Landing, Calif.	0.9		0.6		0.7
St. Lawrence River:					
Massena, N.Y.	2.1		1.6	1.8	
San Juan River:					
Shiprock, N. Mex.					3.2
Savannah River:					
North Augusta, S. C.	1.4	2.1		1.1	
Port Wentworth, Ga.	1.9	2.5	1.0		1.5
Schuylkill River:					
Philadelphia, Pa.	1.3	1.3		1.4	
Shenandoah River:					
Berryville, Va.			0.4		0.4
Ship Creek:					
Anchorage, Alaska	0.5			0.4	

Table 2. Quarterly strontium–90 concentrations in surface waters, July–December 1966 and January–September 1967—Continued

Station	Average concentrations (pCi/liter)					Station	Average concentrations (pCi/liter)				
	July–Sept 1966	Oct–Dec 1966	Jan–Mar 1967	Apr–June 1967	July–Sept 1967		July–Sept 1966	Oct–Dec 1966	Jan–Mar 1967	Apr–June 1967	July–Sept 1967
Snake River:						Truckee River:					
Ice Harbor Dam, Wash.	0.8	1.0		0.6		Farad, Calif.			1.0		0.3
Wawawai, Wash.			0.5		1.3	Wabash River:					
Payette, Idaho			0.4			New Harmony, Ind.			1.8		
South Platte River:						Willamette River:					
Julesburg, Colo.			1.4		1.7	Portland, Ore.			0.3		0.9
Spokane River:						Yakima River:					
Post Falls Dam, Idaho	0.7					Richland, Wash.	0.6	0.3		0.4	
Susquehanna River:						Yellowstone River:					
Sayre, Pa.	2.0	1.2		0.9		Sidney, Mont.	3.7	1.7		2.6	
Conowingo, Md.			1.1		1.2						
Tennessee River:						Maximum	8.6	5.8	3.9	5.1	6.1
Lenoir City, Tenn.	1.2		0.7								
Chattanooga, Tenn.			1.1			Minimum	0.5	0.3	0.3	0.2	0.4
Pickwick Landing, Tenn.	1.4	1.3		0.8	1.2	Median	1.85	2.10	1.10	1.55	1.65
Tombigbee River:											
Columbus, Miss.	1.7	1.3		1.3		Average	2.30	2.12	1.47	1.76	1.98

During July–December 1966 and January–September 1967, this standard was not reached. Comparison between the quarters is not feasible at all sampling locations due to fluctuations in sampling frequencies. Comparisons with results prior to October 1964 should take into consideration an instrument recalibration which resulted in a lowering of strontium–90 values by 15 percent (*11*).

Although Grand Forks, N. Dak., on the Red River has shown maximum quarterly values of strontium–90 in past years, the current quarterly levels for 1967 have shown a decline. On the other hand, the levels at Kingston, Tenn., on the Clinch River below Oak Ridge showed an unusual value in strontium–90 during April–June 1967. An individual strontium–90 determination on a single sample collected May 22, 1967, gave a result of 17.5 pCi/liter. This condition was temporary since the gross beta radioactivity on both the May 22 sample and the following samples contained 70 pCi/liter and 21 pCi/liter, respectively. From June through November of 1967, gross beta radioactivity at this station has been at normally low levels. One value of 44 pCi/liter of gross beta radioactivity was detected in December 1967. Values since that time were low.

REFERENCES

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(*2*) Ibid., 1959 Edition.

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Tritium in Surface Water Network January-June 1968

National Center for Radiological Health
U.S. Public Health Service

The tritium sampling network was established by the Public Health Service in May 1964 to measure and monitor tritium concentrations in major river systems in the United States and to provide surveillance at selected surface water stations downstream from nuclear facilities. The network consists of 10 stations selected from the 131 existing water pollution sampling stations operated by the Federal Water Pollution Control Administration (FWPCA); eight of the stations are located downstream from nuclear facilities and two stations were to establish baseline levels (figure 1). Articles covering the period 1964–1965 (*1*) and 1966 (2) and a data report for 1967 have been published previously in *Radiological Health Data and Reports.*

Monthly composites of weekly samples are collected through the FWPCA and sent to the Southeastern Radiological Health Laboratory for analysis. The analyses are carried out using liquid scintillation counting techniques described by Moghissi et al (*3*). The minimum level of detectability is 0.2 nCi/liter.

Data for the samples collected during the first 6 months of 1968 are shown in table 1. Station averages for this period and the corresponding period of 1967 are also presented in the table. The highest concentration observed during the first 6 months of 1968 was 23.5 nCi/liter (Clinch River - Kingston, Tenn.). The highest 6-month average, 9.6 nCi/liter, was also observed at the Clinch River station. Assuming

Figure 1. Sampling stations for tritium in surface waters

Table 1. Tritium concentration of surface waters, January–June 1968

Collection site	Concentration (nCi/liter) [a]							
	Jan	Feb	Mar	Apr	May	June	Jan-June average [b]	
							1968	1967
Big Sioux River: Sioux Falls, S. Dak	0.6 ±0.2	0.6 ±0.2	0.5±0.2	[c]0.2 ±0.2	0.6 ±0.2	0.4 ±0.2	0.4	1.2
Clinch River: Kingston, Tenn	2.8 ±0.3	2.6 ±0.3	4.6±0.4	14.4 ±0.7	23.5 ±0.9	NS	9.6	4.4
Colorado River: Boulder City, Nev	2.3 ±0.3	2.2 ±0.2	3.6±0.3	2.0 ±0.2	1.7 ±0.2	2.1 ±0.3	2.3	2.6
Columbia River: Northport, Wash [d]	NS	NS	NS	NS	NS	NS	—	1.7
Columbia River: Pasco, Wash	NS	0.8 ±0.2	1.0±0.2	1.4 ±0.2	0.8 ±0.2	0.8 ±0.2	1.0	1.5
Hudson River: Poughkeepsie, N.Y	0.4 ±0.2	0.4 ±0.2	1.6±0.2	0.5 ±0.2	0.4 ±0.2	[b]0.2 ±0.2	.6	1.1
Mississippi River: New Orleans, La [d]	[b]0.2 ±0.2	[b]0.2 ±0.2	0.9±0.2	[b]0.2 ±0.2	[b]0.2 ±0.2	[b]0.2 ±0.2	.2	.7
Ohio River: Wheeling, W. Va	NS	0.7 ±0.2	NS	NS	NS	0.3 ±0.2	.5	.8
Rio Grande: El Paso, Tex	NS	NS	NS	NS	NS	NS	—	.7
Savannah River: Port Wentworth, Ga	3.8 ±0.3	9.4 ±0.5	9.4±0.5	6.5 ±0.4	12.0 ±0.7	3.7 ±0.5	7.5	8.4

[a] The error reported is the two-sigma error at the 95-percent confidence level.
[b] Values less than or equal to the minimum level of detectability (0.2 nCi/liter) were averaged as zero.
[c] Values are not statistically significant at the 95-percent confidence level.
[d] Baseline station.
NS, no sample.

that the specific activity of tritium in the body is essentially the same as that in the surface water, this average concentration corresponds to an estimated whole-body dose[1] of 1.6 mrem/year; or in terms of Federal Radiation Council guidance, approximately 1 percent of the Radiation Protection Guide (170 mrem/year) for an average dose to a suitable sample of the exposed population (*4*). With the exception of the Clinch River station, all stations showed lower 6-month averages for this January-June collection period than for the comparable period in 1967. The 6-month average for the Clinch River station increased from 4.4 to 9.6 nCi/liter.

The samples for the Ohio River station, previously collected at Toronto, Ohio, are now being collected at Wheeling, W. Va. The new sampling location is approximately 50-miles downstream from Toronto.

[1] Development of the calculations to obtain this dose may be found in reference 2.

REFERENCES

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(*2*) MOGHISSI, A. A., and C. R. PORTER. Tritium in surface waters in the United States, 1966. Radiol Health Data Rep 9:337–339 (1968).

(*3*) MOGHISSI, A. A., H. L. KELLEY, J. E. REGNIER, and M. W. CARTER. Low level tritium counting by means of liquid scintillation. (To be published).

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Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
January–December 1967	October 1968

Radioactivity in California Waters[1] July-December 1967

Bureau of Radiological Health
State of California
Department of Public Health

Gross beta radioactivity in California domestic waters is monitored by the State of California's Bureau of Radiological Health. The importance of this program in the State's environmental surveillance activities stems from the fact that most of California's domestic water supplies are of surface origin.

Radioactivity in such water supplies consists of the natural radioactivity in surface streams, radioactivity added by the discharge of sewage or by industrial waste effluents, and radioactivity from fallout, particularly fallout into open terminal or distribution reservoirs. Present efforts consist of sampling raw and treated surface waters and well waters. It should be noted that except for large metropolitan water supplies, raw water sampling is being phased out and treated water sampling being substi-

[1] Data from January and April 1968 issues of Radiological Health News, State of California, Department of Public Health, Bureau of Radiological Health, 2151 Berkeley Way, Berkeley, Calif. 94704.

Figure 1. California surface water sampling stations

Table 1. Gross beta radioactivity in California domestic waters, July–December 1967

Sampling station	Quality	Concentration (pCi/liter)					
		July	August	September	October	November	December
Alturas	Well	NS	NS	NS	[a] 5	ND	[a] 16
Antioch	Treated	8	ND	ND	40	[a] 1	[a] 17
Berkeley	Treated	ND	[a] 8	[a] 6	41	[a] 23	[a] 3
Clearlake Highlands	Treated	ND	[a] 10	ND	ND	ND	59
Crescent City	Well	30	ND	[a] 9	44	[a] 11	[a] 1
Death Valley	Treated	63	[a] 20	[a] 6	29	ND	[a] 18
Dos Palos	Treated	[a] 14	[a] 13	[a] 8	ND	ND	[a] 4
Eureka	Raw	[a] 1	[a] 14	[a] 8	ND	[a] 2	[a] 2
	Treated	NS	ND	ND	[a] 16	ND	[a] 2
Fort Bragg	Treated	NS	NS	NS	[a] 2	28	NS
Lake Arrowhead	Treated	[a] 12	NS	NS	[a] 15	[a] 20	NS
Lake Millerton	Raw	[a] 11	[a] 17	24	ND	[a] 3	[a] 15
Los Angeles	Raw	ND	[a] 35	[a] 11	[a] 4	32	NS
Marin Municipal Water District	Treated	[a] 13	NS	NS	NS	NS	NS
Mariposa	Treated	[a] 7	NS	NS	NS	NS	NS
Metropolitan Water District South Calif:							
Weymouth Plant	Treated	ND	[a] 10	[a] 10	[a] 20	ND	38
Monterey	Treated	ND	[a] 3	NS	NS	[a] 2	36
Napa	Treated	ND	[a] 7	[a] 6	ND	ND	32
Needles	Well	[a] 8	[a] 2	NS	ND	22	272
North Marin Water District	Treated	[a] 4	ND	ND	ND	56	27
	Raw	[a] 3	ND	[a] 5	[a] 23	[a] 19	ND
	Sludge [b]	ND	ND	[a] 11	ND	[a] 18	ND
Oroville:							
Wyandotte Irrigation District	Treated	NS	[a] 7	ND	NS	ND	NS
Pleasanton	Well	ND	[a] 13	ND	[a] 13	ND	[a] 2
Redding	Treated	NS	ND	ND	NS	[a] 6	NS
Sacramento:							
American River	Treated	NS	ND	[a] 1	ND	[a] 6	NS
Sacramento River	Treated	NS	ND	[a] 18	22	[a] 10	NS
Salinas	Well	[a] 8	NS	NS	NS	NS	NS
San Diego	Raw	ND	[a] 4	[a] 20	[a] 24	[a] 13	42
	Treated	[a] 18	ND	[a] 14	ND	[a] 23	[a] 4
San Francisco:							
Water Department	Raw	ND	[a] 9	ND	[a] 10	ND	2
Alameda East	Raw	NS	ND	ND	ND	ND	27
Brightside Weir	Raw	NS	ND	[a] 11	ND	[a] 6	[a] 10
Calavaras Reservoir	Raw	NS	[a] 8	ND	ND	[a] 5	[a] 9
Crystal Springs	Raw	NS	[a] 17	NS	NS	NS	NS
Hetch Hetchy	Raw	ND	[a] 11	[a] 11	ND	ND	ND
San Jose	Raw	[a] 6	ND	ND	[a] 9	[a] 5	NS
San Luis Obispo	Treated	NS	NS	[a] 2	ND	ND	37
Santa Barbara	Treated	ND	[a] 9	[a] 18	[a] 10	ND	ND
Santa Cruz	Treated	NS	[a] 3	[a] 6	ND	ND	NS
Santa Rosa	Raw	[a] 8	ND	ND	[a] 10	[a] 4	[a] 13
Scotia	Raw	ND	[a] 13	ND	53	[a] 1	[a] 2
	Treated	NS	[a] 10	[a] 5	ND	[a] 4	32
Tahoe City	Raw	NS	[a] 5	NS	ND	[a] 4	NS
Ukiah	Well	ND	ND	[a] 5	ND	[a] 6	[a] 9
Vallejo:							
Fleming Hill	Raw	44	[a] 9	[a] 1	ND	ND	[a] 12
	Treated	[a] 19	37	[a] 4	39	[a] 4	ND
Swanzy Reservoir	Treated	[a] 4	ND	29	[a] 4	[a] 18	[a] 11
Willits	Treated	NS	[a] 4	[a] 3	ND	[a] 1	[a] 2
Yosemite	Treated	[a] 6	ND	[a] 14	47	[a] 3	NS
Maximum		63	37	29	53	56	272
Minimum		1	2	1	2	1	1

[a] When the counting rate of the sample is not equal to at least twice the 0.95 error, the value reported is the best estimate, but is not statistically significant.
[b] Sludge reported in pCi/g (dry weight).
ND, nondetectable.
NS, no sample collected.

tuted or continued. This procedural change is predicated upon sampling water at the point of consumption.

Most of the supplies sampled have, as a source, raw surface waters (figure 1), although a few wells, along with some water supplies that use infiltration galleries, are also sampled.

Monitoring of domestic water supplies is on a continuing basis, since it has not been possible to forecast levels of radioactivity in these supplies based upon levels in rain, snow, or surface streams. Under the present sampling schedule, monthly 500 ml samples are collected and the total solids analyzed for alpha and beta radio-

Table 2. Radionuclide concentrations in California surface waters, January–December 1967

Sampling station and date (1967)	Radionuclide concentrations (pCi/liter)						
	Potassium-40	Manganese-54	Strontium-89	Strontium-90	Zirconium-niobium-95	Cesium-137	Radium-226
Antioch:							
January-June	*2	ND	ND	ND	ND	ND	0.03
July-December	1	ND	ND	1	ND	ND	NA
Berkeley:							
January-June	*1	ND	ND	1	ND	ND	ND
July-December	ND	ND	ND	1	ND	ND	.01
Clearlake Highlands:							
January-June	ND	ND	ND	ND	ND	ND	.03
July-December	ND	ND	ND	1	1	ND	.02
CrescentCity:							
July-December	ND	ND	ND	ND	ND	ND	*.01
Death Valley:							
January-June	*9	ND	ND	1	*1	ND	*.14
July-December	*3	ND	ND	ND	*1	ND	*.04
Dos Palos:							
April-September	*1	ND	ND	ND	ND	ND	.09
October-December	*2	*2	ND	*1	*1	ND	*.04
El Centro:							
January-June	*3	ND	ND	1	ND	ND	.29
Eureka:							
January-June	*2	ND	ND	ND	ND	ND	.03
July-December	*1	ND	ND	ND	ND	ND	*.02
Fort Bragg:							
July-December	ND	ND	ND	ND	ND	ND	.01
Lake Millerton:							
April-August	*2	ND	1	1	ND	ND	.03
September-December	ND	ND	ND	1	ND	ND	ND
Marin Municipal Water District:							
July-December	ND	ND	ND	1	ND	ND	*.01
Metropolitan Water District of southern Calif:							
January-June	*3	ND	ND	1	ND	ND	*.04
July-December	*5	ND	ND	1	1	ND	*.03
Monterey:							
April-August	*2	ND	ND	ND	ND	ND	.11
Napa:							
January-June	*3	ND	ND	ND	ND	ND	.04
July-December	*1	ND	ND	1	ND	ND	*.01
Needles:							
January-June	*10	ND	*1	ND	ND	ND	ND
July-December	ND	ND	ND	ND	*1	ND	ND
North Marin Water District:							
January-June	16	1	2	ND	ND	1	ND
July-December	*3	ND	ND	1	ND	ND	.01
Oroville:							
January-June	ND	ND	ND	ND	*1	ND	ND
Pleasanton:							
January-June	*1	ND	2	ND	*1	ND	*.02
July-December	NA	ND	ND	2	ND	*1	NA
Redding:							
January-June	ND	ND	ND	ND	ND	ND	*.02
July-December	*1	ND	ND	ND	1	ND	*.01
Sacramento:							
January-June	*1	ND	ND	ND	ND	ND	*.02
July-December	*1	ND	ND	ND	*1	ND	*.02
San Diego:							
January-June	5	ND	*1	2	ND	ND	*.01
July-December	*2	ND	ND	2	ND	ND	*.10
San Francisco:							
January-August	*2	ND	*1	1	ND	ND	.04
San Jose:							
January-June	*1	ND	ND	ND	ND	ND	*.01
July-December	*1	ND	ND	ND	*1	ND	*.01
Santa Barbara:							
March-August	3	ND	ND	1	ND	ND	ND
Santa Cruz:							
January-June	*2	ND	ND	ND	ND	ND	.04
Santa Rosa:							
July-December	*2	ND	ND	ND	ND	ND	*.02
Scotia:							
July-December	*1	ND	ND	ND	ND	ND	*.02
Tahoe City:							
January-June	ND	ND	*1	ND	ND	ND	.04
Ukiah:							
May-August	*2	ND	ND	ND	ND	ND	*.01
Vallejo:							
January-June	*2	ND	ND	1	ND	ND	*.01
July-December	*1	ND	ND	ND	ND	ND	*.01
Willits:							
July-December	*1	ND	ND	ND	ND	ND	*.01
Yosemite:							
March-August	*1	ND	ND	1	ND	ND	*.01
September-December	*1	*2	ND	1	ND	5	*.02

Results for cerium-141-144 for all stations were nondetectable during this period except for the values of 1 pCi/liter at Needles and 2 pCi/liter at North Marin Water District for January-June 1967.

* When the counting rate of the sample is not equal to at least twice the 0.95 error, the value reported is the best available estimate but is not statistically significant.

NA, no analysis.

ND, nondetectable.

activity. In addition, 3-liter samples are collected monthly for approximately 6 months and composited for specific radionuclide analysis on a semiannual basis.

Analytical procedures

Radionuclide analyses of water are carried out in the State's Sanitation and Radiation Laboratory. Measurements of alpha and alpha-plus-beta radioactivities are made with a low-background windowless gas-flow proportional counter. Counting methods used follow those recommended by the U.S. Public Health Service (*1*).

Individual samples are evaporated to dryness and the residue ashed at 450°C. The ashed sample is dissolved and transferred to an aluminum planchet for beta-particle counting. Specific radionuclides are determined semiannually on composite samples. Gamma-ray emitting nuclides are determined by gamma-ray spectroscopy and radium and radiostrontium by chemical separation and counting.

Discussion

Table 1 shows the monthly average beta radioactivity in the suspended-plus-dissolved solids in surface water supplies in California from July through December 1967. Following treatment, these waters are used for industrial and domestic purposes. Because alpha radioactivity in water has, in general, been undetectable or very slight, alpha radioactivity analyses are not presented. No increase in radioactivity level of surface water has been observed.

Table 2 shows specific radionuclide concentrations in California surface waters of 1967 by stations.

REFERENCE

(*1*) PUBLIC HEALTH SERVICE, DIVISION OF RADIOLOGICAL HEALTH. Radionuclide analyses of environmental samples, R 59–6. Radiological Health Research Activities, Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio 45226 (November 16, 1959).

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
July–December 1966	February 1968
January–June 1967	June 1968

Radioactivity in Kansas Surface Waters, July-December 1967

Kansas State Department of Health
Radiological Health Section

Monitoring of levels of radioactivity in the surface waters of Kansas is done by the Kansas State Department of Health, Radiological Health Section, in cooperation with the Water Data Analysis Section. This surveillance program is important because of both the present and future potential use of Kansas surface waters for domestic, recreational, and industrial purposes.

Liter samples are collected every month at each location shown in figure 1. These samples are analyzed for alpha and beta radioactivity. Radioactivity in these waters consists of the natural radioactivity picked up by flowing streams and percolating ground water, radioactivity from sewage discharge into the streams, and some contribution by industrial waste. The final contributing factor to radioactivity content is fallout, particularly over large expanses of open water, such as reservoirs and lakes.

Analytical procedures

The Radiological and Occupational Health Program does radioactivity analyses using techniques similar to those used in California (*1*).

An appropriate size sample, usually 250 ml, is evaporated in an aluminum planchet and counted after drying in an oven at 100°C and cooling in a desiccator. If much suspended solids are present in the water they are removed by centrifugation before measuring out the sample. Alpha and beta radioactivity counting is done in a gas-flow, windowless internal proportional counter.

Discussion

Table 1 shows the alpha and beta radioactivity in the dissolved solids in Kansas surface waters from July through December 1967.

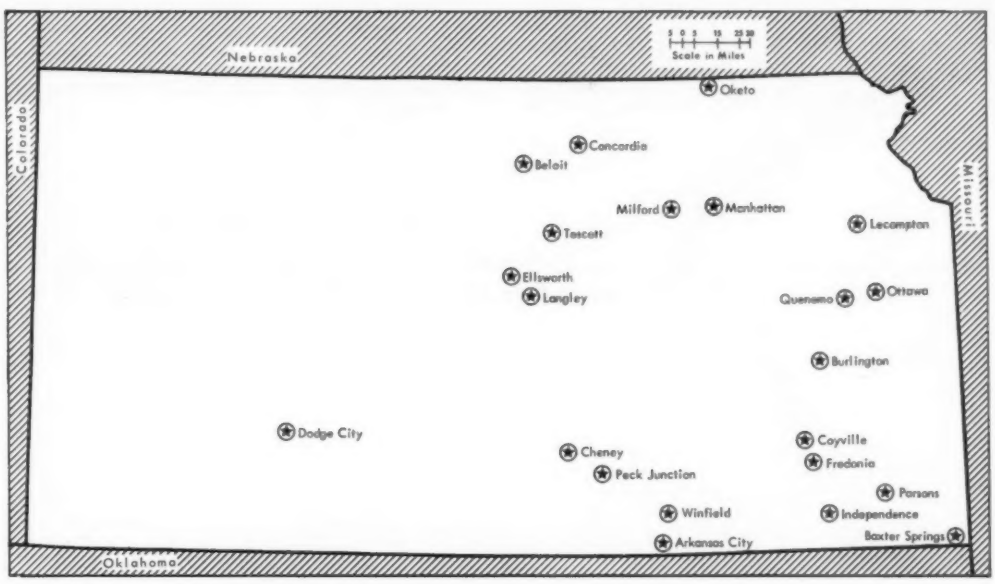

Figure 1. Kansas surface water sampling stations

Table 1. Gross radioactivity in Kansas surface waters, July–December 1967

River and sampling station		Radioactivity concentration (pCi/liter)											
		July		August		September		October		November		December	
		Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta
Arkansas:	Arkansas City	NS	NS	NS	NS	NS	NS	▵3	ND	ND	▵14	▵1	ND
	Dodge City	▵39	▵20	▵9	ND	▵2	▵37	▵23	ND	▵12	ND	▵66	ND
Big Blue:	Oketo	▵1	▵14	▵2	ND	▵2	▵12	NS	NS	▵4	ND	ND	ND
	Manhattan	▵1	▵36	▵1	▵2	ND	ND	NS	NS	▵1	▵12	ND	▵6
Fall:	Fredonia	▵1	▵10	▵3	ND	ND	ND	▵1	▵8	▵1	▵2	▵5	ND
Kansas:	Lecompton	▵1	▵15	▵3	▵28	▵3	▵7	▵1	ND	ND	▵12	ND	▵5
Marais des Cygnes:	Ottawa	▵1	▵24	▵2	▵21	▵2	▵8	▵2	▵9	ND	ND	▵4	ND
Neosho:	Burlington	▵2	▵14	NS	NS	NS	NS	NS	NS	ND	ND	▵2	ND
	Parsons	▵3	▵24	▵1	▵34	ND	▵12	NS	NS	▵2	NS	▵5	▵9
Ninnescah:	Cheney	▵2	▵14	ND	ND	ND	NS	▵6	▵9	NS	NS	NS	NS
	Peck Junction	▵4	ND	16	▵17	NS	NS	ND	▵9	ND	ND	▵5	▵23
Republican:	Concordia	13	▵26	▵4	▵6	NS	NS	▵2	▵2	▵2	▵17	▵1	▵10
	Milford	NS	NS	▵2	▵13	▵2	ND	▵3	▵24	ND	▵17	▵2	▵4
Saline:	Tescott	NS	NS	▵3	▵18	ND	▵12	▵2	▵13	▵15	72	ND	▵1
Smoky Hill:	Ellsworth	NS	NS	NS	NS	NS	NS	▵5	ND	▵6	▵8	▵13	ND
	Langley	NS	NS	NS	NS	NS	NS	ND	ND	▵3	▵3	▵12	▵19
Solomon:	Beloit	▵2	▵23	ND	▵28	▵1	▵29	NS	NS	NS	NS	NS	NS
Spring:	Baxter Springs	▵4	ND	ND	▵16	▵1	▵5	ND	ND	NS	NS	ND	▵12
Verdigris:	Coyville	▵3	▵5	ND	▵17	▵1	▵9	▵1	ND	▵2	ND	▵2	ND
	Independence	▵4	ND	ND	ND	ND	ND	▵1	▵26	▵2	ND	ND	ND
Walnut:	Winfield	▵2	▵9	▵4	ND	ND	▵7	ND	▵20	ND	ND	ND	33

▵ When the counting rate of the sample is not equal to at least twice the 95 percent error, the value reported is not statistically significant but is the best available estimate.
NS, no sample.
ND, nondetectable.

These waters are used for domestic, industrial, and recreational purposes. The analytical techniques prior to July 1967 were different from those now in use so a valid comparison cannot be made of the present results with those previously obtained.

At the present time there is only one surface water sampling station in western Kansas, at Dodge City. This is partly because of the scarcity of surface water in this region. Plans for the future include the development of at least five sampling points in the western portion of the State.

REFERENCE

(*1*) STATE OF CALIFORNIA DEPARTMENT OF PUBLIC HEALTH, BUREAU OF RADIOLOGICAL HEALTH. Radioactivity in California waters, July–December 1966. Radiol Health Data Rep 9:108–111 (1968).

SECTION III. AIR AND DEPOSITION

Radioactivity in Airborne Particulates and Precipitation

Continuous surveillance of radioactivity in air and precipitation provides one of the earliest indications of changes in environmental fission product radioactivity. To date, this surveillance has been confined chiefly to gross beta radioanalysis. Although such data are insufficient to assess total human radiation exposure from fallout, they can be used to determine when to modify monitoring in other phases of the environment.

Surveillance data from a number of programs are published monthly and summarized periodically to show current and long-range trends of atmospheric radioactivity in the Western Hemisphere. These include data from activities of the U.S. Public Health Service, the Canadian Department of National Health and Welfare, the Mexican Commission of Nuclear Energy, and the Pan American Health Organization.

An intercomparison of the above networks was performed by Lockhart and Patterson in 1962 and is summarized in the January 1964 issue of *Radiological Health Data*. In addition to those programs presented in this issue, the following programs were previously covered in *Radiological Health Data and Reports:*

Network	Period	Issue
Fallout Network, HASL	July–December 1967	September 1968
80th Meridian Network, HASL	Calendar year 1965	January 1967

1. Radiation Alert Network July 1968

National Center for Radiological Health
U.S. Public Health Service

Surveillance of atmospheric radioactivity in the United States is conducted by the Radiation Alert Network (RAN) which regularly gathers samples at 73 locations distributed throughout the country (figure 1). Most of the stations are operated by State health department personnel.

The station operators perform "field estimates" on the airborne particulate samples at 5 hours after collection, when most of the radon daughter products have decayed, and at 29 hours after collection, when most of the thoron daughter products have decayed. They also perform field estimates on dried precipitation samples and report all results to appropriate National Center for Radiological Health officials by mail or telephone, depending on levels found. Compilation of the daily field estimates is reported elsewhere on a monthly basis (*1*). A detailed description of the sampling and analytical procedures was presented in the March 1968 issue of Radiological Health Data and Reports.

Table 1 presents the monthly average gross beta radioactivity in surface air particulates and deposition by precipitation, as measured by the field estimate technique during July 1968. Time profiles of gross beta radioactivity in air for eight Radiation Alert Network stations are shown in figure 2.

All field estimates reported were within normal limits for the reporting stations.

Figure 1. Radiation Alert Network sampling stations

Table 1. Gross beta radioactivity in surface air and precipitation, July 1968

Station location		Number of samples	Air surveillance gross beta radioactivity (pCi/m³)			Last profile in RHD&R	Precipitation				
							Number of samples	Total depth (mm)	Field estimation of deposition		
		Air	Maximum	Minimum	Average [a]		Pptn		Number of samples	Depth (mm)	Total deposition (nCi/m²)
Ala:	Montgomery	24	6	0	2	Sept 68	8	122	8	122	55
Alaska:	Adak	31	3	1	2	Apr 68	[e]				
	Anchorage	18	0	0	0	Oct 68	3	17	[d]		
	Attu Island	[b]				May 68	[e]				
	Fairbanks	20	7	0	1	Nov 68	8	38	8	38	43
	Juneau	22	0	0	0	Feb 68	11	129	11	129	0
	Kodiak	23	2	0	1	Mar 68	[e]				
	Nome	[b]				July 68	[e]				
	Pt. Barrow	17	4	0	2	June 68	[e]				
	St. Paul Island	9	1	1	1	Aug 68	[e]				
Ariz:	Phoenix	12	5	1	3	Feb 68	[e]				
Ark:	Little Rock	12	3	0	1	Oct 68	1	20	1	20	0
Calif:	Berkeley	22	0	0	0	Mar 68	[e]				
	Los Angeles	5	3	0	2	July 68	[e]				
C. Z:	Ancon	10	1	0	0	Mar 68	[e]				
Colo:	Denver	23	7	0	2	Mar 68	3	15	[d]		
Conn:	Hartford	21	1	0	0	Nov 68	5	39	5	39	6
Del:	Dover	21	2	0	1	Sept 68	[e]				
D. C:	Washington	17	2	0	1	June 68	3	22	3	22	0
Fla:	Jacksonville	20	1	0	1	Oct 68	7	189	7	189	144
	Miami	20	1	0	0	Nov 68	9	203	8	158	0
Ga:	Atlanta	20	2	1	1	Aug 68	8	148	8	148	105
Guam:	Agana	20	1	0	0	Sept 68	[e]				
Hawaii:	Honolulu	31	1	0	1	May 68	[e]				
Idaho:	Boise	20	4	1	3	May 68	[e]				
Ill:	Springfield	2	4	1	2	June 68	1	63	0	0	[e]
Ind:	Indianapolis	20	3	1	2	Aug 68	3	20	3	20	34
Iowa:	Iowa City	22	4	0	2	Mar 68	4	59	4	59	0
Kans:	Topeka	22	4	0	2	Oct 68	8	246	8	246	0
Ky:	Frankfort	2	1	1	1	June 68	1	9	1	9	28
La:	New Orleans	22	1	0	0	June 68	9	151	[d]		
Maine:	Augusta	21	1	0	0	July 68	6	90	6	90	0
Md:	Baltimore	22	2	0	1	Nov 68	3	30	3	30	12
	Rockville	14	2	0	1	May 68	[e]				
Mass:	Lawrence	[b]				Sept 68	5	41	0	0	[e]
	Winchester	21	3	0	1	Apr 68	6	16	6	16	0
Mich:	Lansing	21	7	0	2	May 68	6	72	6	72	209
Minn:	Minneapolis	22	1	0	0	Sept 68	6	145	6	145	53
Miss:	Jackson	21	2	0	1	July 68	4	163	4	163	150
Mo:	Jefferson City	22	4	0	1	Aug 68	5	87	5	87	0
Mont:	Helena	22	6	1	3	Apr 68	3	12	3	12	9
Nebr:	Lincoln	20	6	1	3	Aug 68	8	93	8	93	7
Nev:	Las Vegas	20	6	1	3	Nov 68	[e]				
N. H:	Concord	20	3	1	1	June 68	[e]				
N. J:	Trenton	21	3	0	1	July 68	2	56	2	56	16
N. Mex:	Santa Fe	21	1	0	1	Apr 68	9	62	8	61	15
N. Y:	Albany	20	3	0	1	Aug 68	1	23	1	23	15
	Buffalo	21	4	0	1	Mar 68	[e]				
	New York City	21	2	0	1	Apr 68	[e]				
N. C:	Gastonia	16	6	1	4	Mar 68	3	31	[d]		
N. Dak:	Bismark	22	4	0	1	June 68	3	12	3	12	0
Ohio:	Cincinnati	[b]				Sept 68	[e]				
	Columbus	15	3	0	1	July 68	5	49	4	45	0
	Painesville	22	2	0	1	Nov 68	8	99	8	99	11
Okla:	Oklahoma City	22	4	0	1	May 68	3	18	3	18	6
	Ponca City	24	4	0	2	Nov 68	3	54	3	54	
Ore:	Portland	21	3	0	0	Aug 68	3	17	3	17	
Pa:	Harrisburg	7	2	1	2	Aug 68	[e]				
P. R:	San Juan	[b]				July 68	[e]				
R. I:	Providence	9	2	0	1	May 68	2	21	2	21	4
S. C:	Columbia	22	2	0	1	Apr 68	8	242	7	236	29
S. Dak:	Pierre	15	8	1	3	Feb 68	[e]				
Tenn:	Nashville	16	2	0	1	May 68	6	143	6	143	4
Tex:	Austin	21	5	0	3	Sept 68	4	84	[d]		
	El Paso	21	10	1	2	June 68	[e]				
Utah:	Salt Lake City	29	2	1	1	July 68	1	3	1	3	2
Vt:	Barre	14	2	1	1	Oct 68	7	94	7	94	0
Va:	Richmond	17	1	0	1	Oct 68	3	62	3	62	32
Wash:	Seattle	20	0	0	0	Oct 68	3	11	[d]		
	Spokane	22	4	0	2	Sept 68	[e]				
W. Va:	Charleston	19	3	0	1	Apr 68	9	150	9	150	23
Wis:	Madison	23	1	0	1	Oct 68	7	84	7	84	55
Wyo:	Cheyenne	22	3	1	1	Nov 68	3	25	3	25	32
Network summary		1,275	10	0	1		3	75	5	78	27

[a] The monthly average is calculated by weighting the field estimates of individual air samples with length of sampling period.
[b] Indicates no report received. (Air samples showing no field estimate are ignored.)
[c] Indicates no precipatation sample collected.
[d] Indicates that the station is part of the plutonium in precipitation network. No gross beta measurements are done.
[e] Samples were collected but no field estimates were reported.

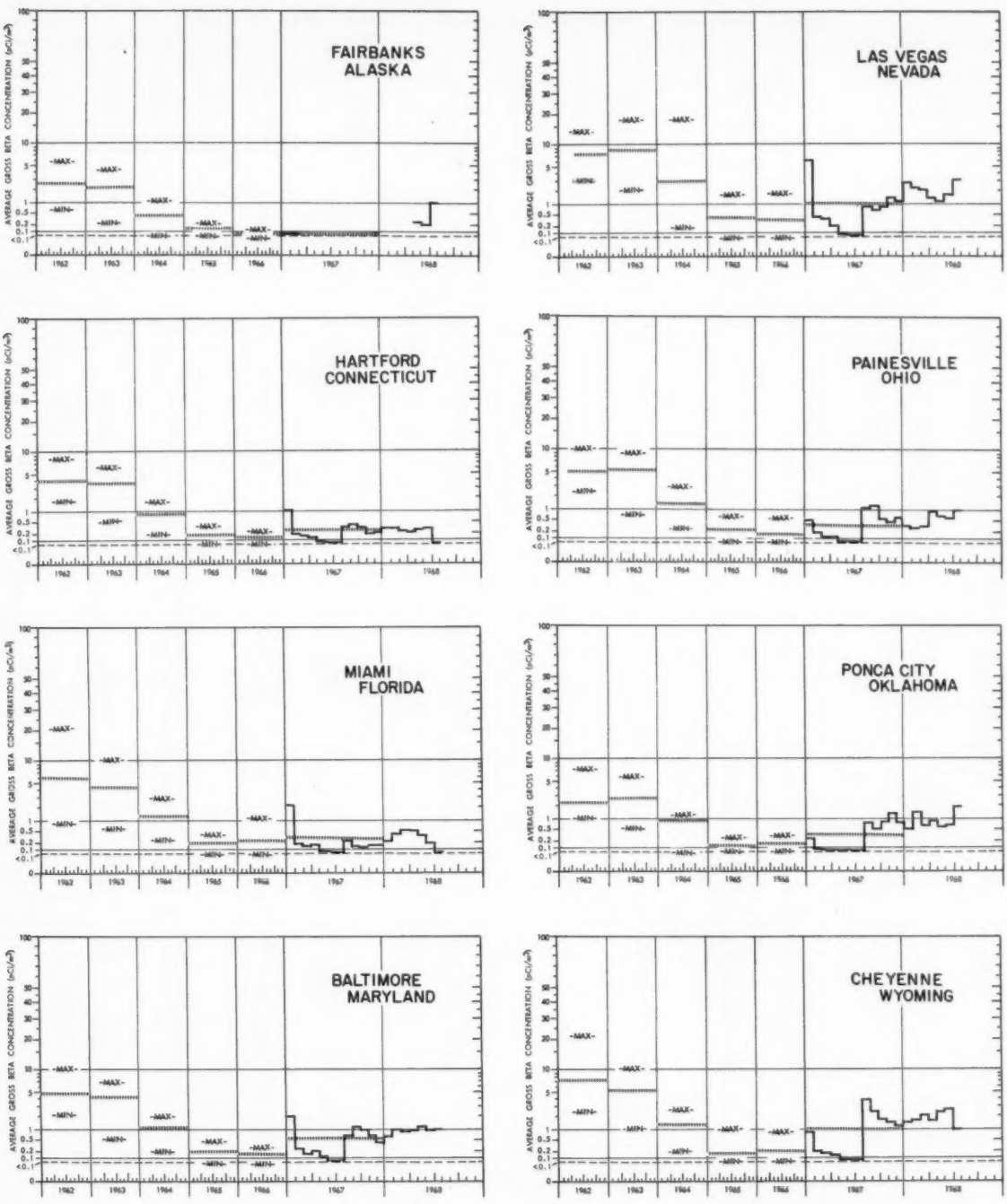

Figure 2. Monthly and yearly profiles of beta radioactivity in air—Radiation Alert Network, 1962–July 1968

2. Canadian Air and Precipitation Monitoring Program,[1] July 1968

Radiation Protection Division
Department of National Health and Welfare

The Radiation Protection Division of the Canadian Department of National Health and Welfare monitors surface air and precipitation in connection with its Radioactive Fallout Study Program. Twenty-four collection stations are located at airports (figure 3), where the sampling equipment is operated by personnel from the Meterological Services Branch of the Department of Transport. Detailed discussions of the sampling procedures, methods of analysis, and interpretation of results of the radioactive fallout program are contained in reports of the Department of National Health and Welfare (*2–6*).

A summary of the sampling procedures and methods of analysis was presented in the October 1968 issue of *Radiological Health Data and Reports.*

Surface air and precipitation data for July 1968 are presented in table 2.

Table 2. Canadian gross beta radioactivity in surface air and precipitation, July 1968

Station	Number of samples	Air surveillance gross beta radioactivity (pCi/m³)			Precipitation measurements	
		Maximum	Minimum	Average	Average concentrations (pCi/liter)	Total deposition (nCi/m²)
Calgary	31	0.4	0.0	0.2	26	1.7
Coral Harbour	23	.1	.0	.0	32	3.4
Edmonton	31	.3	.0	.2	109	6.4
Ft. Churchill	31	.2	.0	.1	71	3.7
Ft. William	31	.3	.0	.1	58	9.8
Fredericton	30	.3	.0	.2	73	2.1
Goose Bay	31	.2	.0	.2	65	8.2
Halifax	30	.3	.1	.2	143	2.1
Inuvik	31	.3	.0	.1	350	1.6
Montreal	30	.4	.1	.2	NS	NS
Moosonee	31	.3	.0	.2	9	1.4
Ottawa	31	.3	.0	.2	91	5.3
Quebec	9	.1	.0	.1	71	4.7
Regina	31	.4	.0	.2	226	6.5
Resolute	27	.1	.0	.0	13	.1
St. John's, Nfld	31	.3	.0	.1	51	3.2
Saskatoon	31	.4	.0	.1	86	9.5
Saulte Ste Marie	28	.3	.0	.2	170	10.8
Toronto	31	.4	.0	.2	14	.7
Vancouver	31	.2	.0	.1	159	4.0
Whitehorse	31	.2	.0	.1	168	5.3
Windsor	31	.3	.0	.2	37	4.9
Winnipeg	31	.3	.0	.2	49	7.1
Yellowknife	31	.2	.0	.1	208	2.5
Network summary	704	0.4	0.0	0.1	99	4.6

NS, no sample.

[1] Prepared from information and data in the August 1968 monthly report "Data from Radiation Protection Program," Canadian Department of National Health and Welfare, Ottawa, Canada.

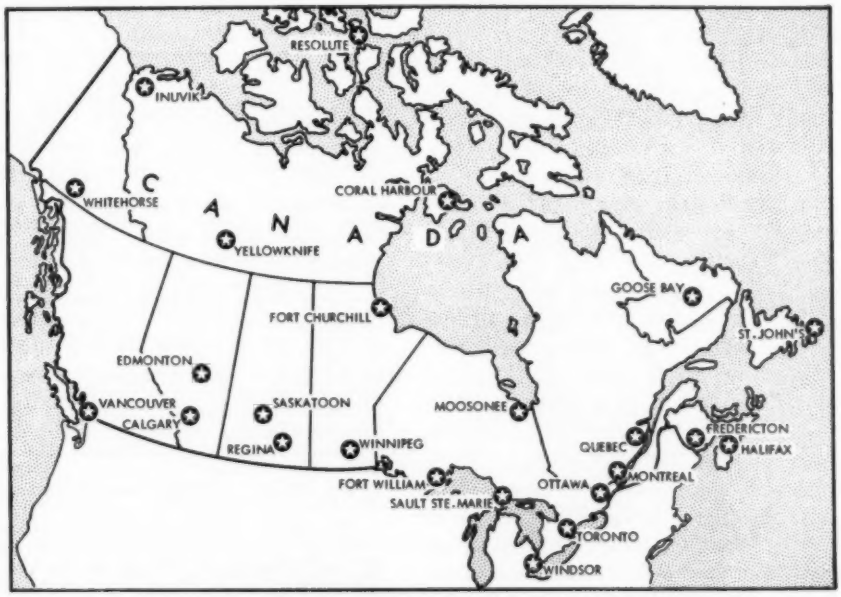

Figure 3. Canadian air and precipitation sampling stations

3. Pan American Air Sampling Program July 1968

Pan American Health Organization and *U.S. Public Health Service*

Gross beta radioactivity in air is monitored by countries in the Americas under the auspices of the collaborative program developed by the Pan American Health Organization (PAHO) and the U.S. Public Health Service (PHS) to assist PAHO-member countries in developing radiological health programs.

The air sampling locations are shown in figure 4. It should be noted that a new sampling station has been established in Georgetown, Guyana, bringing the total number of participating countries to ten. Analytical techniques were described in the January 1968 *Radiological Health Data and Reports*. The July 1968 air monitoring results from the participating countries are given in table 3. A noticeable increase in the monthly average concentration of gross beta radioactivity was seen in La Paz, Bolivia; Santiago, Chile; and to a lesser extent in Guayaquil, Ecuador. Listed in table 5 are the samples from these stations in which fresh fission products were identified.

Figure 4. Pan American Air Sampling Program stations

Table 3. Summary of gross beta radioactivity in Pan American surface air, July 1968

Station location	Number of samples	Gross beta radioactivity (pCi/m³)		
		Maximum	Minimum	Average [a]
Argentina: Buenos Aires	7	0.06	0.01	0.03
Bolivia: La Paz	13	9.81	.03	2.85
Chile: Santiago	29	3.87	.01	.31
Colombia: Bogota	16	.09	.01	.03
Ecuador: Guayaquil	25	.54	.01	.09
Guyana: Georgetown	2	.13	.09	.11
Jamaica: Kingston	16	.12	.03	.09
Lima: Peru	15	.08	.01	.03
Venezuela: Caracas	20	.37	.01	.12
West Indies: Trinidad	20	.16	.01	.07
Pan American summary	163	9.81	0.01	0.34

[a] The monthly average is calculated by weighting the individual samples with length of sampling period. Values less than 0.005 pCi/m³ are reported and used in averaging as 0.00 pCi/m³.

Table 4. PAHO air samples in which fresh fission products were identified by gamma spectroscopy

Location		Date (1968)	
Ecuador:	Guayaquil	July	30
Bolivia:	La Paz	July	15
			17
			18
			22
			25
			26
			29
			30
Chile:	Santiago	July	26
			27
			28
			29

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SECTION IV. OTHER DATA

This section presents results from routine sampling of biological materials and other media not reported in the previous sections. Included here are such data as those obtained from human bone sampling, bovine thyroid sampling, Alaskan surveillance and environmental monitoring around nuclear facilities.

Summary of Natural Environmental Gamma Radiation Using a Calibrated Portable Scintillation Counter[1]

National Center for Radiological Health

A portable gamma scintillation counter (PGSC) for field use was developed by the National Center for Radiological Health (*4*) for use in an epidemiological study (*1*). This instrument was calibrated with a highly sensitive muscle equivalent ionization chamber, whose readings convert directly to μrad/hr for 6mm muscle depth at 5 feet above the ground (*2*). The ionization chamber required at least 2 hours for a set of readings at one site, whereas the portable unit requires only 2 minutes per reading. The PGSC uses a 2-inch NaI(Tl) crystal, weighs 12 pounds, is contained within an attaché case, and provides an automatic timer and a digital read-out in counts-per-minutes (cpm). Extensive calibration runs, which paired PGSC and ionization chamber reading under normal environmental background radiation conditions were made during development, field testing and actual field measurements (*3*). These showed that the standard error using the PGSC was 0.35 μrad/hr and the readings were within 4 percent of the ionization chamber readings 95 percent of the time. A bivariate linear function (*4*) was used to convert the PGSC values in cpm to equivalent ionization chamber readings in μrad/hr. An altitude correction was included in this formula to adjust for the decreased sensitivity of the crystal to high energy cosmic radiation which increases at higher elevations. Using the PGSC units, readings were taken over grass or soil in populated areas. Six different PGSC units were used and these were periodically intercalibrated in a round-robin procedure. The sensitivity of the PGSC units was adjusted to give a consistent reading, using a 3 μCi cadmium–109 source, between readings. Simultaneous measurements which were later used to calibrate the PGSC, were made with the ionization chamber and a PGSC at one or two sites in each town.

The data presented in this report were obtained during three separate periods and the precision is in part indicated by the number of readings per town. Phase 1 included 4,624 measurements in 53 towns in Michigan, Minnesota, and Colorado made between October and

[1] Written by Mr. S. G. Levin, PSP, NCRH; Mr. R. K. Stoms, Mr. E. Kuerze, and Mr. W. Huskisson, Instrument Development Unit, Electronic Products Radiation Lab, TSB, NCRH, Cincinnati, Ohio 45226.

December 1965 at 0.2 mile intervals and provide average dose rates for the selected towns. A more detailed description of this study and an indication of the variability of the readings is presented elsewhere (*3*). Phase 2 measurements constituted a broad survey of 1,131 towns in 19 east coast States made in the summer of 1966. One to thirty measurements were made in each town, depending upon size, generally in the vicinity of a highway, but away from areas of disturbed soil or other man-made surfaces, in an attempt to locate high natural background radiation areas. The PGSC units were calibrated with the ionization chamber in only a few towns during this 12-week survey. Phase 3 measurements were made in 114 towns in Illinois and Iowa to complement a previous epidemiological study (*5*) of the possible effects of radium in well water. This phase was conducted much as that of phase 2, and 4 to 16 readings per town were made between October and December 1966.

Interpretation

The towns in this study were not randomly selected, nor were they selected in a manner such that they would be considered representative of the States of the nation as a whole. In each phase the number and location of the sites of the measurements were determined to best accomplish the objectives of the specific studies.

Figure 1 shows the sites where one or more environmental radiation dose rate measurements were made. It was not possible to make contour lines showing background radiation levels because the measurements were not spaced with this in mind. Table 1 presents the average values for each town where measurements were made. Average values by States are not presented because the measurements made at the various sites in a State would not necessarily represent the State as a whole.

The average dose rate ranged from 5.1 μrad/hr east of Facil, Fla., to 14.6 μrad/hr in Fort Morgan, Colo. The values within a State, and very often within several adjacent States, were relatively uniform with occasional high values in the vicinity of phosphate mines, mine tailings, etc. The coastal areas of Florda and North Carolina generally had low background levels (5–7 μrad/hr); eastern and central States were intermediate with 7 to 12 μrad/hr and the Rocky Mountain areas measured were in the 11 to 15 μrad/hr range.

The data contained in this report provide useful estimates of the outdoor natural background radiation levels in certain populated areas. Since other studies (*6*) have shown that the indoor levels are highly correlated with outdoor levels but are on the average 0.7 as high, inferences about population exposure are possible in those areas covered by the study.

Summary and conclusions

Environmental radiation dose rate measurements which include the contribution from terrestrial and cosmic components were obtained using a portable gamma scintillation counter, which was calibrated with a muscle-equivalent ionization chamber. Measurements were made in 1,298 towns of 24 states in areas where people live and work.

These data may be used to calculate genetically significant doses if other relative data are obtained, such as estimates of the number of persons represented by the measurements, the relative amount of time that individuals are exposed indoors and outdoors, the variation of the background radiation as a function of time, and the relative amount of time people spend outside of the specific area.

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Figure 1. Sites where one or more background gamma radiation dose rate measurements were made

Table 1. Average values of background gamma dose rate measurements using portable gamma scintillation counters

State and city		Latitude	Longitude	Altitude	Average (μrad/hr)	Number of observations
Colo:	Cannon City	38.26	105.16	5350	13.9	50
	Craig	40.31	107.33	6174	13.5	27
	Ft. Collins	40.35	105.05	4965	13.5	109
	Ft. Morgan	40.15	103.48	4550	14.6	57
	Grand Junction	39.07	108.32	4585	13.9	99
	Greeley	40.25	104.41	4663	13.4	138
	La Junta	38.03	103.31	4100	11.6	51
	Lamar	38.07	102.36	3515	12.1	56
	Rocky Ford	38.02	103.42	4250	12.7	40
	Sterling	40.37	103.12	3939	12.9	68
	Trinidad	37.10	104.29	6200	13.5	65
Conn:	Ashford	41.53	72.08	565	10.0	1
	Berlin	41.40	72.43	350	9.7	3
	Bethel	41.21	73.26	450	10.4	6
	Bolton	41.47	72.27	400	8.7	1
	Bradford	41.15	72.52	40	10.3	4
	Bridgeport	41.10	73.08	7	10.4	5
	Clinton	41.15	72.33	30	8.4	4
	Coscob	41.03	73.35	150	11.4	5
	Coventry	41.48	72.21	480	9.1	1
	Danbury	41.23	73.28	510	9.9	8
	Darien	41.06	73.26	70	10.8	
	Dodgingtown	41.22	73.23	600	10.4	2
	East Hartford	41.47	72.38	120	8.9	6
	East River	41.16	72.38	40	8.6	2
	Eastford	41.54	72.05	540	12.2	3
	Fairfield	41.08	73.15	10	11.1	3
	Guilford	41.16	72.42	30	9.0	3
	Hartford	41.46	72.42	140	9.9	5
	Jewett City	41.38	71.54	400	9.9	3
	Leetes Corner	41.15	72.45	30	12.5	3
	Madison	41.16	72.35	40	9.0	4
	Manchester	41.48	72.29	392	9.1	7
	Mansfield	41.50	72.16	600	9.8	3
	Middlebury	41.33	73.09	800	10.4	2
	Milford	41.12	73.05	30	9.1	5
	Milldale	41.35	72.53	550	9.1	3
	Moosup	41.42	71.52	325	9.3	4
	New Britain	41.41	72.48	200	9.9	3
	New Canaan	41.09	73.30	100	10.8	4
	New Haven	41.17	73.05	25	9.1	12
	New London	41.20	72.05	40	10.4	9
	Newtown	41.23	73.19	700	9.5	4
	Niantic	41.18	72.15	20	11.0	5
	Norwalk	41.07	73.25	37	11.3	6
	Norwich	41.32	72.04	20	10.8	8
	Old Saybrook	41.19	72.18	40	9.3	3
	Pine Orchard	41.15	72.50	30	10.2	2
	Plainfield	41.40	71.53	350	9.1	3
	Plantsville	41.37	72.46	400	8.8	4
	Ridgefield	41.15	73.30	450	10.2	4
	Sound View	41.17	72.17	10	11.4	4
	Southington	41.38	72.45	350	9.4	2
	Southbury	41.28	73.17	900	9.1	4
	Stamford	41.05	73.33	190	11.1	5
	Sterling	41.41	71.49	300	9.8	3
	Stoney Creek	41.16	72.47	30	10.2	1
	Stratford	41.11	73.06	20	10.4	6
	Ucasville	41.28	72.06	20	10.8	3
	Warrenville	41.51	72.10	575	11.8	1
	Waterbury	41.35	73.02	605	10.3	10
	West Hartford	41.45	72.44	150	9.6	7
	Westbrook	41.18	72.26	40	9.6	4
	Westport	41.08	73.25	20	10.9	3
	Wilton	41.12	73.27	300	11.0	3
	Woodbury	41.34	73.16	935	9.5	2
	Woodstock	41.55	72.03	540	11.9	2
Del:	Blackbird	39.20	75.39	35	9.2	1
	Dover	39.09	75.31	25	8.6	7
	Farmington	38.55	75.35	30	8.6	1
	Greenwood	38.50	75.35	40	7.9	2
	Newark	39.40	75.44	90	10.1	4
	Newport	39.45	75.35	80	9.8	3
	Odessa	39.28	75.40	40	9.9	2
	Seaford	38.37	75.37	55	7.9	3
	Symrna	39.15	75.38	35	8.7	3
	Wilmington	39.40	75.36	78	9.8	15
Fla:	Buchanan	27.26	81.50	80	5.9	2
	Bunnel	29.28	81.08	50	6.2	5
	Bushnell	28.40	82.05	75	6.5	4
	Callahan	30.33	81.47	25	9.0	5
	Caloosahatchee River	26.45	81.26	16	7.7	2
	Canal Point	26.52	80.38	25	6.5	3
	Casselberry	28.46	81.14	15	6.1	3
	Charlotte	26.58	82.05	10	6.2	3

Table 1. Average values of background gamma dose rate measurements using portable gamma scintillation counters—continued

State and city		Latitude	Longitude	Altitude	Average (μrad/hr)	Number of observations
Fla:	Chiefland	29.27	82.54	40	6.5	3
	Citrus	28.29	82.39	18	6.1	2
	City Point	28.28	80.49	28	6.0	2
	Cleveland	26.59	81.58	10	5.5	2
	Coachman	28.04	82.40	8	6.2	1
	Cocoa	28.26	80.48	27	6.3	5
	Coleman	28.45	82.04	19	6.3	2
	Collier	26.30	81.26	10	5.7	5
	Connersville	29.16	81.20	40	6.2	2
	Copeland	25.58	81.23	4	8.3	2
	Crescent Park	29.25	81.30	58	6.9	4
	Cross City	29.38	83.08	43	7.2	3
	Crystal River	28.50	82.40	15	5.9	5
	Dade City	28.20	82.06	18	7.7	3
	Dania	26.04	80.12	7	6.0	5
	De Bary	28.53	81.17	40	6.1	4
	De Leon Springs	29.12	81.18	40	6.8	4
	De Sota	27.03	81.55	15	5.9	1
	Deerfield Beach	26.20	80.05	20	5.9	3
	Deland	29.04	81.17	40	6.3	8
	Delray Beach	26.28	80.05	15	6.1	4
	Denver	29.22	81.27	50	6.6	1
	Dinsmore	30.28	81.45	24	7.4	2
	Dupont Center	29.29	81.09	50	6.5	4
	Durbin	30.04	81.25	15	6.4	2
	East Palatka	29.39	81.37	20	6.5	3
	East of Facil	30.19	82.46	175	5.1	3
	East Tampa	27.58	82.32	25	8.0	4
	Eau Gallie	28.06	80.37	15	5.9	6
	Econfina River	30.23	83.40	100	7.2	4
	Edgewater	28.58	80.54	30	7.4	4
	Eldred	27.27	80.15	30	6.2	3
	Eldridge	29.14	81.19	40	7.2	2
	Estero	26.28	81.51	15	6.7	2
	Favorita	29.20	81.06	40	5.9	2
	Facil	30.19	82.47	160	8.3	1
	Florida City	25.25	80.30	11	6.8	3
	Ft. Drum	27.35	80.51	60	6.0	2
	Ft. Lauderdale	26.06	80.10	16	6.6	30
	Ft. Meade	27.43	81.49	122	9.2	5
	Ft. Myers	26.35	81.52	15	7.5	4
	Ft. Ogden	27.05	81.54	25	6.1	2
	Ft. Pierce	27.28	80.21	30	6.2	7
	Frontenac	28.34	80.50	30	5.9	2
	Gainsville	29.38	82.22	86	7.4	6
	Garden Cove	25.13	80.29	14	6.1	3
	Gardner	27.24	81.51	70	6.2	2
	Genoa	30.25	82.51	160	6.9	2
	Gibsonton	27.55	82.30	25	6.7	2
	Goulds	25.35	80.24	11	7.8	4
	Greater Miami	25.43	80.17	15	6.5	14
	Green Cove	30.00	81.45	17	6.9	5
	Hague	29.47	82.29	85	6.5	1
	Hardeetown	29.28	82.55	42	6.3	4
	Hernando	28.25	82.40	20	5.7	1
	Hibernia	30.03	81.43	17	7.1	2
	High Spring	29.50	82.36	75	7.5	7
	Highland Cove	27.57	81.53	175	9.7	5
	Hilliard	30.40	81.48	25	7.6	3
	Hobe Sound	27.04	80.10	10	6.7	2
	Hollandale	25.59	80.16	15	6.3	3
	Hollywood	26.03	80.13	10	5.9	5
	Holopaw	28.09	81.10	50	5.7	3
	Homeland	27.45	81.50	125	9.8	1
	Homestead	25.30	80.30	11	7.2	4
	Homosassa	28.38	82.39	18	5.9	2
	Hopewell	28.01	82.10	100	8.2	3
	Hudson	28.20	82.42	10	6.1	2
	Iamonia	31.34	84.19	48	8.5	3
	Immokolee	26.28	81.26	10	6.3	5
	Indian River	28.36	80.50	30	7.3	1
	Indrio	27.31	80.23	30	6.5	3
	Inglis	29.02	82.41	12	6.2	3
	Islamorada	24.52	80.39	4	5.8	2
	Jacksonville	30.25	81.39	24	7.9	28
	Jasper	30.29	82.55	140	6.8	2
	Junction route 415 and 192	28.08	81.08	50	5.8	1
	Jensen Beach	27.15	80.14	15	5.9	4
	Jerome	26.00	81.22	4	7.5	2
	Juno Beach	26.48	80.08	10	6.3	3
	Jupiter	26.55	80.09	10	6.0	2
	Keanansville	27.50	81.00	60	5.8	3
	Key Colony	25.00	80.40	11	5.8	2
	Key Largo	25.09	80.28	10	6.4	3

Table 1. Average values of background gamma dose rate measurements using portable gamma scintillation counters—continued

State and city		Latitude	Longitude	Altitude	Average (μrad/hr)	Number of observations
Fla:	Key West	24.33	81.48	6	6.2	13
	Kirkwood	29.26	82.11	70	6.8	1
	Kissimmee	28.17	81.25	60	5.9	3
	Kronoa	29.24	81.07	40	5.9	3
	Lake City	30.11	82.36	205	7.3	6
	La Grange	28.38	80.51	35	6.8	2
	Lake Polk	27.55	81.45	100	6.0	1
	Lake Worth	26.39	80.06	15	6.0	4
	Lakeland	28.02	81.57	214	8.2	8
	Lamont	30.24	83.55	213	7.8	6
	Lantana	26.38	80.05	15	5.7	3
	Laurel	27.12	82.27	15	7.4	1
	Lebanon Station	29.15	82.39	12	6.7	4
	Lee & Charlotte County	26.45	81.45	10	5.8	3
	Lokosee	27.43	80.57	60	5.8	2
	Long Beach	24.25	81.20	10	6.9	2
	Long Key	24.45	80.49	4	5.6	4
	Lowell	29.15	82.08	80	12.1	3
	Malabar	28.00	80.34	15	6.1	2
	Marathon	24.40	81.10	11	5.9	4
	Margate	26.25	80.08	18	6.1	6
	Martin	29.13	82.08	80	9.8	1
	Matecumbe Beach	24.48	80.44	4	5.6	1
	McIntosh	29.25	82.10	75	8.1	3
	Mecca	28.06	82.42	8	6.2	3
	Melbourne	28.04	80.36	10	6.0	4
	Miami	25.43	80.17	15	6.8	11
	Micanopy	29.26	82.11	75	6.5	1
	Micco	27.50	80.32	20	6.0	2
	Miles City	26.11	81.22	10	6.8	1
	Mims	28.40	80.51	35	6.6	3
	Modello	25.32	80.29	10	8.1	4
	Moultrie	29.45	81.20	15	6.5	2
	Naples	26.13	81.51	15	5.9	5
	Naranja	25.33	80.28	10	7.5	3
	National	29.17	81.05	40	6.1	3
	New Smyrna	29.01	80.55	30	6.9	4
	Nittaw	27.56	81.00	60	5.7	2
	Nocatee	27.08	81.53	40	6.5	2
	Nokomis	27.10	82.27	10	7.0	2
	N. Palm Beach	26.45	80.08	10	6.0	4
	N. Port Charles	27.02	82.08	30	6.8	3
	Nursery Grove	27.52	80.33	20	6.0	2
	Oak Hill	28.50	80.53	30	6.1	3
	Ocala	29.11	82.08	86	10.0	5
	Ochopee	25.55	81.15	15	6.2	6
	Ojus	25.58	80.16	15	6.0	4
	Okeechobee	27.13	80.48	34	5.9	5
	Orange City	28.57	81.18	40	6.5	4
	Orange Lake	29.23	82.09	80	8.3	2
	Orange Park	30.05	81.40	18	8.0	5
	Orlando	28.33	81.20	108	6.5	8
	Ormond Beach	29.09	81.03	30	7.4	5
	Oslo	27.32	80.24	30	6.2	3
	Osowaw Junction	27.30	80.52	60	6.0	2
	Osprey	27.17	82.27	15	6.3	2
	Otter Creek	29.20	82.40	10	6.2	3
	Oxford	28.55	82.03	18	7.8	1
	Pahokee	26.46	80.38	10	6.5	4
	Palatka	29.39	81.38	15	6.7	5
	Palm Bay	28.02	80.35	10	6.4	3
	Palm Shore	28.13	80.41	15	5.8	2
	Palmeto	27.30	82.28	15	6.9	4
	Pembroke	27.44	81.50	125	10.6	1
	Perrine	25.36	80.21	11	7.2	3
	Perry	30.07	83.36	45	6.9	5
	Pierson	29.15	81.20	40	6.3	3
	Pineda	28.20	80.45	15	6.0	2
	Piney Point	27.32	82.28	15	5.5	1
	Pinto Drive	29.11	81.03	31	6.7	13
	Point Laurel	25.27	80.20	14	5.9	3
	Pomona Park	29.33	81.37	45	6.7	3
	Pompano Beach	26.14	80.09	22	6.4	6
	Port Charlotte	27.02	82.08	10	6.7	7
	Port Mayac	26.59	80.37	38	6.1	3
	Port Richey	28.15	82.45	8	7.7	3
	Port Salerno	27.11	80.17	10	5.9	4
	Poxsee	27.45	80.59	60	5.8	2
	Princeton	25.34	80.26	11	7.7	3
	Punta Gorda	26.58	81.58	9	6.6	5
	Ramrod Key	24.25	81.20	10	6.4	2
	Reddick	29.22	82.09	80	9.1	1
	Relief Channel	24.49	80.42	4	5.4	2
	Rio	27.14	80.14	10	5.5	1
	Riviera Beach	26.43	80.07	14	6.1	5

Table 1. Average values of background gamma dose rate measurements using portable gamma scintillation counters—continued

State and city		Latitude	Longitude	Altitude	Average (μrad/hr)	Number of observations
Fla:	Rock Harbor	25.06	80.29	5	5.9	2
	Rockledge	28.25	80.48	20	6.0	2
	Royal Palm	26.39	80.06	20	6.2	8
	Ruskin	27.35	82.30	15	6.1	4
	Salem	29.45	83.30	45	6.2	3
	San Carlos	26.30	81.52	15	7.4	2
	San Mateo	29.35	81.37	30	6.8	2
	Sand Cut	26.55	80.38	30	6.2	3
	Sanford	28.48	81.15	14	6.6	7
	Santos	29.09	82.06	86	8.0	1
	Sarasota	27.21	82.32	30	7.6	7
	Satsuma	29.34	81.38	30	6.5	3
	Scotts Moor	28.45	80.52	30	6.8	3
	Sebastian	27.45	80.31	20	6.0	3
	Seville	29.17	81.25	40	6.6	3
	Shamrock	29.39	83.09	43	5.9	3
	Sharpes	28.29	80.49	30	6.1	3
	South Venice	27.03	82.20	30	6.0	1
	St. Augustine	29.53	81.20	15	7.2	9
	St. Cloud	28.13	81.23	50	5.8	4
	St. Johns	30.11	81.29	15	6.4	1
	St. Lucie	27.30	80.22	30	6.8	3
	St. Petersburg	27.46	82.38	8	7.0	21
	Stuart	27.13	80.15	10	6.0	4
	Summerfield	29.01	82.03	15	8.3	1
	Summerland	24.25	81.25	8	6.1	3
	Sumpterville	28.42	82.04	19	6.4	1
	Sun City	27.34	82.29	15	5.0	1
	Sunbeam	30.15	81.35	15	6.7	3
	Sunniland	26.20	81.25	10	6.8	2
	Tallahassee	30.23	84.22	55	8.9	7
	Tampa	27.58	82.32	19	8.0	11
	Tarpon Springs	28.09	82.45	8	6.9	3
	Tavernier	25.01	80.31	5	6.0	6
	Titusville	28.37	80.50	40	5.9	5
	Tomoka Estates	29.13	81.04	40	6.4	3
	Trilacodches	28.30	82.05	18	9.4	1
	Turnbull	28.43	80.52	32	6.7	1
	Up The Grove	27.05	80.42	40	5.4	2
	Valhalla	24.55	80.45	11	6.2	2
	Valkaria	27.56	80.34	15	6.0	2
	Valroy	27.33	82.28	15	5.3	1
	Venice	27.06	82.27	10	6.6	1
	Vero Beach	27.38	80.27	20	8.0	6
	Wabasso	27.43	80.30	20	6.0	3
	Walton	27.20	80.14	15	6.1	5
	Wauchula	27.35	81.49	119	6.8	6
	Waukeenah	30.23	83.58	150	8.3	4
	Weekiwachee	28.27	82.40	18	6.6	2
	Wesconnet	30.13	81.39	20	7.9	3
	West Palm Beach	26.41	80.06	15	6.1	13
	White City	27.26	80.20	30	5.9	3
	White Springs	30.17	82.45	190	6.5	3
	Wildwood	28.50	82.03	19	6.9	3
	Williams Port	28.32	80.50	30	6.4	1
	Winfield	30.15	82.45	195	7.1	2
	Winter Beach	27.41	80.28	20	7.1	3
	Yeehaw Junction	27.40	80.55	60	5.8	3
	Yukon	30.10	81.39	20	7.5	3
	Yulee	30.29	81.33	25	8.3	3
	Zelfo Springs	27.30	81.50	90	6.8	3
	Zephyrhill	28.13	82.05	18	6.7	3
Ga:	Adairsville	34.21	84.56	720	10.4	3
	Adel	31.07	83.25	240	7.9	4
	Albany	31.32	84.08	180	8.4	8
	Americus	32.06	84.10	476	8.6	6
	Arabi	31.43	83.39	400	8.3	3
	Ashburn	31.40	83.37	435	8.5	5
	Atlanta	33.39	84.26	1010	10.6	9
	Barnesville	33.07	84.09	600	14.5	4
	Beachton	30.50	83.59	200	8.8	2
	Broadhurst	31.27	81.53	100	8.2	2
	Brunswick	31.09	81.30	10	8.5	17
	Butler	32.33	84.14	625	9.1	5
	Calhoun	34.29	84.58	650	9.4	2
	Camilla	31.14	84.13	175	8.4	5
	Cartersville	34.09	84.50	685	10.5	7
	Cecil	31.03	83.24	245	8.0	1
	Chula	31.32	83.33	375	8.1	1
	Claxton	32.09	81.53	180	8.0	3
	Colesburg	30.55	81.40	20	8.9	2
	Cordele	31.58	83.47	305	8.2	6
	Culloden	32.53	84.04	500	13.4	3

Table 1. Average values of background gamma dose rate measurements using portable gamma scintillation counters—continued

State and city		Latitude	Longitude	Altitude	Average (μrad/hr)	Number of observations
Ga:	Dalton	34.46	84.57	720	9.1	6
	Darien	31.20	81.27	15	11.4	7
	Donegal	32.15	81.48	175	8.0	1
	Dougherty	31.28	84.11	150	8.9	3
	Echota	34.32	84.58	650	10.8	1
	Ellaville	32.10	84.13	500	8.6	3
	Eulonia	31.30	81.30	15	9.1	3
	Fender	31.15	83.30	300	8.3	1
	Folkstone	30.48	82.02	30	7.5	6
	Florida and Georgia Line	30.50	83.19	270	6.9	3
	Ft. Valley	32.34	83.51	490	9.0	3
	Freedman	31.46	81.30	60	8.8	1
	Garden City	32.04	81.13	40	9.3	3
	Glennville	31.56	81.55	175	8.0	7
	Glynco	31.45	81.20	15	10.3	1
	Griffin	33.15	84.16	980	12.4	5
	Hahira	30.58	83.23	250	8.6	3
	Henderson	32.27	83.45	425	9.0	1
	Hickox	31.08	81.59	50	8.8	2
	Hortense	31.10	81.53	100	8.6	3
	Inaha	31.34	83.34	0	9.0	1
	Junction route 301 and 24	32.54	81.04	200	8.5	2
	Jesup	31.37	81.53	100	7.7	6
	Kingsland	30.45	81.40	30	9.2	3
	Lee Pope	32.38	83.53	400	9.0	1
	Leesburg	31.40	84.08	200	8.8	2
	Lenox	31.12	83.26	230	8.0	2
	Ludowici	31.40	81.51	150	7.9	3
	Marietta	33.58	84.28	800	9.6	4
	Meigs	31.04	84.05	190	8.0	2
	Midway	31.45	81.30	60	8.1	3
	Milner	33.12	84.11	575	14.2	3
	Musella	32.47	83.58	455	9.5	1
	Nahunta	31.11	81.58	71	8.6	3
	Ochlocknee	30.58	84.03	200	9.0	2
	Orchard Hill	33.14	84.13	565	9.2	1
	Pelham	31.07	84.08	180	8.7	3
	Perry	32.35	83.45	450	8.9	4
	Pike and Spaulding Counties	33.15	84.20	750	10.5	1
	Pike and Upton Counties	33.00	84.19	700	10.1	1
	Pinehurst	32.20	83.46	350	7.6	2
	Resaca	34.34	84.57	650	9.9	1
	Riceboro	31.42	81.30	15	8.7	4
	Richmond Hill	31.47	81.30	80	9.3	4
	Ringgold	34.55	85.07	820	9.5	2
	Roberta	32.43	83.55	435	12.7	6
	Schley and Taylor County	32.13	84.13	575	8.9	3
	South Atlanta	33.31	84.21	930	11.7	1
	South Savannah	31.58	81.17	25	8.7	1
	Savannah	32.08	81.12	22	9.5	14
	Statesboro	32.13	81.50	150	8.4	8
	Sparks	31.09	83.25	235	7.9	2
	Smithville	31.55	84.10	300	9.2	2
	Stone Mt. Park	33.45	84.15	1500	11.8	2
	Sycamore	31.38	83.35	400	8.2	3
	Sylvania	32.45	81.39	254	8.5	6
	Thomaston	32.52	84.19	665	10.5	7
	Thomasville	30.52	84.00	230	8.6	5
	Tifton	31.28	83.31	360	8.3	6
	Tillman	30.55	83.22	250	8.4	1
	Unadilla	32.22	83.45	400	8.3	3
	Valdosta	30.52	83.20	265	8.0	5
	Vienna	32.10	83.47	325	7.8	3
	Waverly	31.07	81.51	70	9.1	3
	Wenona	31.45	83.40	350	7.8	2
	Wentworth	32.07	81.13	46	8.3	3
	White Oak	31.03	81.40	20	9.0	2
	Winokur	31.01	81.60	40	8.9	2
	Woodbine	30.58	81.40	20	8.6	4
	Zebulon	33.13	84.19	725	11.6	3
Ill:	Abington	40.45	90.30	650	9.3	7
	Armington	40.14	89.24	500	9.2	4
	Atlanta	40.12	89.19	500	9.3	5
	Auburn	39.32	89.55	600	9.7	6
	Aurora	41.45	88.20	744	8.1	16
	Batavia	41.45	88.15	700	7.9	6
	Belleville	38.30	89.51	450	9.8	9
	Benld	39.10	89.50	600	9.9	6
	Brimfield	40.48	89.55	600	9.7	5
	Bushnell	40.32	90.33	600	9.4	9
	Carlyle	38.38	89.20	501	9.6	6
	Carthage	40.25	91.15	500	9.1	6
	Charleston	39.29	88.11	710	8.8	8
	Crete	41.27	87.38	660	9.3	6
	Creve Coeur	40.38	89.40	600	9.2	6

Table 1. Average values of background gamma dose rate measurements using portable gamma scintillation counters—continued

State and city		Latitude	Longitude	Altitude	Average (μrad/hr)	Number of observations
Ill:	De Kalb	41.50	88.40	800	8.1	13
	Dixon	41.50	89.29	696	7.6	12
	Dwight	41.07	88.30	475	9.7	6
	Elgin	42.02	88.17	820	8.5	14
	Elmhurst	41.50	87.55	500	8.5	14
	Elmwood	40.45	90.10	600	9.6	1
	Farmington	40.40	90.00	630	9.7	7
	Freeburg	38.27	86.56	550	9.8	6
	Fulton	41.54	90.09	592	8.2	6
	Galesburg	40.57	90.23	771	9.4	3
	Galva	41.10	90.02	855	9.1	6
	Geneva	41.43	88.13	700	7.8	6
	Glencoe	42.05	87.45	600	8.5	7
	Jerseyville	39.06	90.21	630	9.6	6
	Joliet	41.32	88.05	520	8.1	15
	Kewanee	41.15	89.55	820	9.0	10
	Knoxville	40.55	90.32	700	9.7	6
	Lake Bluff	42.30	87.50	600	8.6	6
	Lincoln	40.09	89.22	591	9.0	6
	Lemont	41.40	87.55	500	9.0	6
	Lansing	41.35	87.30	500	8.6	9
	Lockport	41.34	88.05	585	8.5	6
	Marshall	39.23	87.41	570	8.2	6
	Mattoon	39.28	88.21	718	9.1	9
	Milstadt	38.20	90.08	400	9.9	6
	Monmouth	40.55	90.38	770	9.1	8
	Morris	41.21	88.26	520	8.7	6
	Morrison	41.49	89.58	603	8.3	6
	Mount Vernon	38.19	88.55	500	9.5	7
	Nashville	38.23	89.20	515	9.7	6
	New Athens	38.15	86.50	600	9.8	6
	Odin	38.38	89.04	500	9.1	6
	Oglesby	41.15	89.04	500	8.2	6
	Oregon	42.00	89.20	690	8.2	6
	Ottawa	41.22	88.50	474	8.7	6
	Paxton	40.30	88.15	475	8.8	6
	Peoria Heights	40.42	89.41	600	9.0	6
	Pittsfield	39.37	90.45	640	9.3	8
	Rock Island	41.30	90.30	500	8.3	15
	Roxanna	38.49	90.09	500	8.6	6
	Sandwich	41.39	88.35	700	8.3	6
	Silvis	41.30	90.15	700	8.5	6
	South Pekin	40.30	89.55	600	8.1	6
	Staunton	39.03	89.50	550	9.9	6
	Sterling	41.45	89.34	600	8.4	12
	Tremont	40.31	89.50	600	9.3	6
	Urbana	40.06	88.14	743	9.4	11
	Waukegan	42.22	87.52	680	8.7	16
	Waverly	39.32	90.05	600	9.7	5
	Wilmington	41.15	88.05	600	8.4	6
	Winchester	39.32	90.30	500	9.0	6
	Wood River	38.50	90.08	480	8.5	7
Iowa:	Alden	42.31	93.19	1100	8.0	6
	Algona	43.04	94.18	1230	8.6	7
	Atkins	42.00	91.50	750	8.8	6
	Aurelia	42.40	95.30	1100	9.3	6
	Belle Plaines	41.54	92.16	855	8.5	6
	Bellevue	42.16	90.25	603	8.1	6
	Blue Grass	41.30	90.38	500	8.9	6
	Boxholm	42.10	94.10	900	9.0	6
	Bristow	42.45	92.52	1000	8.5	6
	Cedar Rapids	41.53	91.42	840	8.5	21
	Cherokee	42.47	95.33	1250	9.4	8
	Churdan	42.08	94.15	950	9.3	6
	Clarion	42.43	93.45	1165	8.2	6
	Clear Lake	43.10	93.22	1100	8.6	6
	Clinton	41.50	90.13	595	8.6	14
	Colfax	41.30	93.08	925	9.5	6
	Danville	40.52	91.20	700	8.9	6
	De Witt	41.49	90.34	685	8.7	7
	Donnellson	40.42	91.24	715	8.4	7
	Dubuque	42.24	90.42	1056	8.5	17
	Dysart	42.12	92.15	900	8.6	6
	Estherville	43.24	94.50	1298	8.7	7
	Eldridge	41.38	90.35	500	8.7	6
	Fairfield	41.02	91.57	754	8.8	8
	Ft. Dodge	42.31	94.10	1111	8.5	12
	Garner	43.08	93.38	1150	8.8	7
	Grinnell	41.43	92.44	910	8.8	7
	Holstein	42.29	95.32	1370	9.8	7
	Hopkinton	42.20	91.08	800	7.8	6
	Iowa City	41.39	91.32	640	8.9	12
	Jesup	42.30	91.58	900	8.0	6
	Kingsley	42.35	95.55	1000	10.2	6

Table 1. Average values of background gamma dose rate measurements using portable gamma scintillation counters—continued

State and city		Latitude	Longitude	Altitude	Average (μrad/hr)	Number of observations
Iowa:	Lake City	42.16	94.44	1235	9.0	7
	Manchester	42.30	91.25	900	8.3	7
	Marcus	42.45	95.50	1000	10.2	6
	Marengo	41.45	92.06	800	8.6	6
	Mason City	43.09	93.20	1194	8.5	12
	Morning Sun	41.08	91.08	500	9.3	6
	Mt. Pleasant	40.58	91.33	720	9.2	10
	New Hampton	43.03	92.18	1155	8.1	7
	New London	40.56	91.30	700	9.1	7
	Nora Spring	43.11	93.00	1100	8.6	6
	Northwood	43.27	93.13	1210	8.4	7
	Oskaloosa	41.17	92.41	770	9.7	8
	Ossian	43.12	91.45	1100	9.2	6
	Ottumwa	41.06	92.27	842	9.0	12
	Oxford	41.44	91.37	600	8.9	6
	Pella	41.25	92.55	870	9.3	6
	Pottsville	43.10	91.32	1100	8.8	6
	Reinbeck	42.15	92.35	900	8.7	6
	Rockwell City	42.24	94.37	1210	8.9	6
	Sergeant Bluffs	42.25	96.28	900	10.2	5
	Sioux City	42.24	96.23	1095	9.7	20
	Springville	42.08	91.25	800	8.2	6
	Stacyville	43.27	92.45	1100	8.7	6
	Stanhope	42.15	93.45	1000	8.8	6
	Waterloo	42.33	92.24	868	8.3	20
	Waverly	43.18	92.28	1000	9.1	8
	West Bend	42.55	94.30	1000	8.8	6
	West Liberty	41.32	91.10	600	9.0	7
	West Point	40.35	91.29	700	8.6	6
	Winfield	41.10	91.28	550	9.0	6
	Wyoming	42.07	91.00	800	8.6	6
Ky:	Bracht	38.52	84.40	860	9.8	1
	Burnside	36.58	84.34	1100	8.9	2
	Camp Dick	37.45	84.35	1100	10.9	3
	Camp Nelson	37.45	84.35	1100	11.3	1
	Camp Robinson	37.44	84.36	1100	10.8	2
	Corinth	38.20	84.34	890	10.2	2
	Crittenden	38.49	84.39	870	9.3	2
	Dry Ridge	38.46	84.38	900	8.8	1
	Edgewood	39.03	84.44	800	9.7	1
	Erlanger	39.01	84.45	800	9.3	2
	Eubank	37.23	84.35	1200	9.7	3
	Lancaster	37.37	84.35	1032	9.4	2
	Lake Side	39.04	84.44	800	9.4	1
	Georgetown	38.12	84.33	888	9.4	4
	Florence	39.00	84.46	800	9.5	3
	Lexington	38.02	84.36	966	9.7	6
	Mason	38.37	84.35	900	9.8	1
	Nicholasville	37.50	84.33	1000	9.1	2
	Pine Knot	36.40	84.29	1300	8.0	2
	Richwood	38.58	84.45	825	9.3	2
	Sherman	38.47	84.39	880	10.1	1
	Sloans Valley	36.50	84.32	1250	9.4	1
	Somerset	37.06	84.37	955	9.1	3
	South Mitchell	39.05	84.43	800	9.8	1
	Stanford	37.25	84.40	955	9.3	2
	Stearns	36.43	84.29	1420	8.0	2
	Strunk	36.38	84.28	1300	7.6	1
	Walton	38.56	84.43	850	9.9	2
	Whitley City	36.45	84.30	1300	9.4	3
	Williamston	38.39	84.37	920	9.8	3
Maine:	Ashland	46.33	68.28	100	8.8	2
	Auburn	44.06	70.16	180	10.4	3
	Augusta	44.19	69.47	250	9.9	8
	Bangor	44.48	68.49	202	9.6	9
	Beddington	44.52	68.03	1000	9.6	1
	Belfast	44.24	69.00	20	9.3	5
	Biddeford	43.30	70.27	80	11.1	5
	Bridgewater	46.24	67.51	450	9.0	3
	Brunswick	43.54	69.56	70	10.6	3
	Bucksport	44.33	68.40	20	9.8	4
	Burnham	44.39	69.31	95	9.3	3
	Calais	45.10	67.12	130	9.9	7
	Camden	44.14	69.05	50	9.8	5
	Caribou	46.52	68.01	624	9.6	5
	Carmel	44.48	69.04	175	9.4	3
	Clifton	44.52	68.09	500	9.2	2
	Clinton	44.38	69.30	95	9.6	4
	Columbia Falls	44.38	67.48	35	10.3	2
	Costigen	45.01	68.40	100	9.0	3
	Dedham	44.52	68.10	500	9.7	2
	Eagle Lake	47.05	68.36	300	9.4	2
	Ellsworth	44.32	68.26	24	10.2	5
	Etna	44.48	69.06	150	9.4	2

Table 1. Average values of background gamma dose rate measurements using portable gamma scintillation counters—continued

State and city		Latitude	Longitude	Altitude	Average (μrad/hr)	Number of observations
Maine:	Fort Kent	47.15	68.36	530	9.0	5
	Freeport	43.50	70.04	40	10.9	3
	Gorham	43.40	70.30	50	11.3	3
	Gouldboro	44.30	68.05	30	9.9	2
	Grawford	45.05	67.32	100	9.7	2
	Gray	44.07	70.17	150	12.7	9
	Greenfield	45.04	68.37	150	9.1	3
	Grindstone	45.45	68.35	500	9.1	2
	Hancock	44.32	68.15	20	10.2	3
	Haynesville	45.50	67.59	380	9.4	3
	Hermon	44.48	69.00	190	9.6	3
	Houlton	46.08	67.50	410	9.1	3
	Kennebunk	43.25	70.30	100	10.9	3
	Kittery	43.00	70.45	40	9.4	6
	Lewiston	44.06	70.14	182	11.1	3
	Lincoln	45.25	68.30	212	9.9	3
	Linneus	46.04	67.58	390	10.2	2
	Littleton	46.20	67.50	425	9.0	2
	Machias	44.43	67.28	40	10.0	5
	Machias River	44.54	67.54	130	9.6	1
	Macwahoc	45.35	68.09	350	9.4	1
	Mars Hill	46.32	67.51	500	8.9	3
	Massardis	46.30	68.27	100	8.9	7
	Matawamkea	45.30	68.20	200	9.6	3
	Medway	45.35	68.31	600	9.4	1
	Milbridge	44.32	67.56	30	9.9	4
	Milford	44.58	68.40	100	9.0	2
	Milford City	44.58	68.40	100	9.2	1
	Monticello	46.28	67.50	440	8.9	3
	Newport	44.46	69.25	100	9.5	3
	Nobleboro	44.10	69.20	80	10.1	2
	Northport	44.19	68.58	30	8.8	2
	Ogunquit	43.15	70.32	45	10.0	1
	Orono	44.52	68.42	115	9.2	3
	Palermo	44.23	69.30	200	9.1	4
	Passadum	45.07	68.40	150	9.1	3
	Patten	45.59	68.27	800	9.5	3
	Perry	44.55	67.08	50	10.8	3
	Pittsfield	44.42	69.30	100	9.7	2
	Plaisted	47.08	68.36	400	9.5	2
	Portage	46.40	68.30	100	8.8	3
	Portland	43.39	70.19	47	10.9	10
	Presque Isle	46.39	68.00	606	9.0	5
	Saco	43.30	70.27	80	11.2	6
	Sanford	43.23	70.50	100	11.7	4
	Scarboro	43.35	70.22	100	11.2	9
	Searsmount	44.25	69.08	150	9.2	2
	Sherman Station	45.50	68.27	600	9.1	3
	South Bath	43.54	69.54	70	10.3	3
	South Kittery	43.05	70.45	40	9.7	3
	South Lincoln	45.18	68.35	175	9.6	3
	Thomaston	44.10	69.10	70	9.2	4
	Waterville	44.33	69.39	89	9.5	5
	Waterboro	43.30	70.48	75	10.7	3
	Wells	43.20	70.31	60	10.2	4
	Wesley	44.56	67.38	50	10.0	3
	West Aurora	44.52	68.09	500	9.6	3
	Whiting	44.45	67.15	30	9.4	5
	Winslow	44.31	69.39	89	9.5	3
	Winterville	47.02	68.37	500	8.6	3
	Winthrop	44.19	69.55	200	9.6	4
	Wiscassett	44.00	69.18	100	9.7	3
	York	43.10	70.42	40	10.1	2
	York Harbor	43.10	70.42	40	10.3	1
Md:	Baltimore	39.17	76.37	14	8.0	17
	Bel Air	39.30	76.27	20	8.4	5
	Brentwood	38.57	76.58	70	7.2	1
	Calvert	39.43	76.07	60	9.1	2
	Cambridge	38.34	76.09	20	8.3	8
	College Park	38.59	76.56	70	8.4	4
	Conowingo	39.39	76.10	40	8.6	2
	Delmar	38.26	75.35	20	9.2	1
	Eden	38.16	75.39	12	7.7	1
	Elkridge	39.12	76.42	20	9.3	4
	Fairhill	39.45	76.06	70	9.5	3
	Fruitland	38.18	75.37	10	8.1	1
	Hyattsville	38.57	76.58	70	8.6	2
	Kingsville	39.26	76.32	18	8.0	3
	Laurel	39.06	76.54	400	8.9	4
	Pocomoke City	38.03	75.34	20	7.8	2
	Princess Anne	38.12	75.41	15	7.8	2
	Rising Sun	39.41	76.08	50	8.6	3
	Salisbury	38.22	75.35	10	7.7	8
	Savage	39.08	76.52	40	8.9	3

Table 1. Average values of background gamma dose rate measurements using portable gamma scintillation counters—continued

State and city	Latitude	Longitude	Altitude	Average (μrad/hr)	Number of observations
Md: Vienna	38.30	76.07	20	7.9	3
Westover	38.08	75.42	17	8.6	2
Mass: Acton	42.28	71.28	100	11.1	3
Auburn	42.08	71.54	800	11.6	8
Barnstable	41.38	70.15	20	9.4	6
Beverly	42.34	70.52	40	10.3	5
Boston proper	42.22	71.02	15	9.8	36
Brewster	41.45	70.08	40	9.6	4
Chelmsford	42.33	71.20	90	10.2	6
Cohasset	42.14	70.48	20	9.2	1
Dennis	41.42	70.09	20	10.4	7
Duxbury	42.03	70.45	40	8.5	6
East Sandwich	41.46	70.30	20	9.8	2
Essex	42.45	70.47	60	9.7	2
Gleasondale	42.25	71.32	400	10.6	3
Gloucester	42.37	70.40	60	11.4	7
Harwich	41.39	70.07	30	8.0	6
Haverhill	42.46	71.06	60	10.8	8
Hudson	42.23	71.32	400	10.3	3
Hyannis	41.41	70.16	35	9.7	5
Lawrence	42.42	71.10	57	10.4	9
Lexington	42.39	71.00	90	9.6	8
Littleton	42.31	71.21	100	11.0	3
Lowell	42.39	71.19	90	10.4	5
Lynn	42.28	70.35	20	10.1	4
Magnolia	42.35	70.45	60	11.0	4
Manchester	42.35	70.46	60	10.5	4
Manomet	41.50	70.35	30	9.3	13
Marlboro	42.20	71.30	500	10.7	4
Marshfield	42.05	70.33	40	8.8	8
Maynard	42.25	71.29	100	10.3	4
Merrimac	42.55	71.02	40	10.2	3
Methuen	42.44	71.13	55	9.5	1
Newburyport	42.50	70.55	20	10.5	5
North Carver	41.55	70.45	25	8.8	6
North Scituate	42.13	70.45	20	8.7	1
Northboro	42.18	71.38	700	10.2	4
Orleans	41.47	70.00	40	8.3	7
Plymouth	41.59	70.42	25	9.8	11
Quincy	42.15	71.00	15	9.7	9
Rowley	42.45	70.55	50	9.7	8
Sagamore	41.45	70.35	20	9.4	3
Salem	42.32	70.52	26	10.1	5
Sandwich	41.46	70.30	20	9.3	4
Saugus	42.25	70.58	20	10.0	2
Scituate	42.12	70.45	20	8.9	1
South Essex	42.37	70.47	60	10.3	3
South Yarmouth	41.39	70.16	35	8.0	2
Southbridge	42.03	72.05	720	12.3	6
Taunton	41.54	71.04	20	9.7	9
Wakefield	42.30	71.04	30	10.0	6
Waterville	41.54	71.00	20	9.3	2
West Yarmouth	41.41	70.14	35	9.1	4
Weymouth	42.13	70.58	15	9.7	3
Winchester	42.00	71.09	90	9.8	9
Wingham	42.14	70.55	30	9.6	6
Woburn	42.20	71.10	90	9.7	1
Worchester	42.16	71.52	986	11.1	9
Yarmouth	41.38	70.15	20	9.2	5
Ypswich	42.40	70.52	80	9.6	7
Mich: Adrian	41.55	84.01	800	9.2	126
Albion	42.15	84.46	940	8.0	82
Alpena	45.04	83.34	903	7.2	107
Benton Harbor	42.08	86.26	642	7.2	104
Big Rapids	43.42	85.29	928	7.4	66
Charlotte	42.33	84.50	880	7.7	58
Grand Haven	43.04	86.13	603	7.1	83
Holland	42.42	86.06	680	7.3	145
Iron Mountain	45.50	88.04	1164	8.2	107
Ishpeming	46.29	87.39	1419	8.5	80
Jackson	42.17	84.24	1000	7.9	227
Kingsford	45.50	88.04	1164	8.5	52
Lapier	43.02	83.20	844	8.4	77
Marquette	46.34	87.24	1419	8.4	100
Mason	42.34	84.30	880	7.7	51
Midland	43.37	84,15	628	7.4	244
Mt. Pleasant	43.35	84.46	755	7.2	88
Petoskey	45.23	84.58	700	6.6	63
Romeo	42.49	83.01	730	8.3	51
Saulte St. Marie	46.28	84.22	580	8.2	111
South Haven	42.24	86.17	663	7.3	73
Tecumseh	41.58	83.58	815	8.7	72
Three Rivers	41.56	85.38	830	8.0	88
Traverse City	44.45	85.37	623	6.8	99

Table 1. Average values of background gamma dose rate measurements using portable gamma scintillation counters—continued

State and city		Latitude	Longitude	Altitude	Average (μrad/hr)	Number of observations
Minn:	Alexandria	45.52	95.23	1425	8.5	64
	Cloquet	46.42	92.31	1278	9.1	87
	Crookston	47.48	96.36	800	8.9	56
	Eveleth	47.25	92.30	1376	9.4	3
	Fairmont	43.38	94.28	1161	8.9	86
	Falcon Hts	44.58	93.25	900	8.6	44
	Faribault	44.16	93.17	1054	8.5	104
	Fergus Falls	46.17	96.04	1510	8.8	87
	Hibbing	47.23	92.51	1352	9.2	95
	Little Falls	45.59	94.21	1118	8.5	76
	Mankato	44.04	93.58	1005	8.4	135
	Morris	45.35	95.55	1134	8.6	53
	Owatonna	44.06	93.14	1147	8.5	101
	Rochester	43.55	92.30	1310	8.8	242
	St. Peter	44.18	93.58	907	8.4	63
	Thief River Fall	48.04	96.11	1115	8.3	56
	Wadena	46.26	95.08	1350	8.5	50
	Worthington	43.37	95.36	1572	9.1	85
N. C:	Battleboro	36.01	77.46	107	10.3	3
	Belgrade	34.51	77.20	45	7.5	2
	Bishop	34.15	78.00	35	7.7	2
	Bolivia	34.05	78.12	39	7.2	3
	Bolton	34.18	78.25	45	7.9	3
	Bowdens	35.06	78.08	158	6.9	2
	Bridgeton	35.05	77.02	18	7.2	2
	Burgaw	34.25	77.55	40	7.8	4
	Calypso	35.09	78.07	163	8.3	2
	Castle Hay	34.18	77.50	30	8.6	3
	Cerro Gordo	34.18	78.56	60	8.3	1
	Chadbourn	34.18	78.52	65	7.3	3
	Chocowinity	35.30	77.04	10	7.9	4
	Delco	34.17	78.20	39	7.2	3
	Dixon	34.36	77.35	10	7.5	1
	Dudley	35.18	78.03	100	7.0	2
	Edenton	36.03	76.37	20	8.5	5
	Elizabeth	36.19	76.13	8	8.0	7
	Enfield	36.11	77.41	111	9.2	4
	Fair Bluff	34.18	78.79	60	7.1	3
	Faison	35.06	78.09	160	7.6	2
	Folkstone	34.33	77.40	10	6.9	1
	Freeman	34.18	78.22	42	7.9	1
	Fremont	35.43	77.59	104	9.2	3
	Garysburg	36.27	77.35	80	8.1	3
	Goldsboro	35.21	78.01	82	8.2	9
	Grissettown	34.10	78.40	20	6.8	2
	Halifax	36.21	77.38	91	8.4	3
	Hallsboro	34.18	78.38	55	8.0	1
	Hampstead	34.25	77.27	10	8.7	1
	Hartford	36.09	76.30	20	8.3	3
	Holly Ridge	34.30	77.60	10	6.6	3
	Jacksonville	34.45	77.24	14	7.2	5
	Junction route 301 and 11	35.43	77.56	145	9.6	1
	Kellum	34.48	77.22	35	8.6	2
	Lake Waccama	34.18	78.30	50	7.8	3
	Leland	34.15	78.05	30	7.1	2
	Macon	34.16	78.15	35	7.5	1
	Magnolia	34.35	78.04	154	7.2	3
	Maysville	34.50	77.18	44	7.2	3
	Morgans Corner	36.24	76.18	8	7.8	1
	Mt. Olive	35.12	78.04	165	7.9	5
	New Bern	35.05	77.02	18	7.5	6
	Odgen	34.22	77.31	13	6.5	1
	Pikeville	34.43	78.00	100	8.4	4
	Pollocksville	35.00	77.18	44	8.2	3
	Rhems	35.01	77.18	0	9.2	2
	Rocky Mount	35.58	77.48	104	10.8	14
	Rose Hill	34.39	78.02	151	7.6	5
	Scotts Hill	34.23	77.30	10	8.2	3
	Shallotte	34.00	78.27	40	7.6	4
	Sharpesburg	35.56	77.49	100	10.2	4
	South Mills	36.24	76.18	8	7.4	4
	Supply	34.03	78.24	39	7.3	2
	Vanceboro	35.19	77.03	14	9.0	4
	Verona	34.39	77.25	10	7.9	2
	Wallace	34.50	78.00	54	8.0	6
	Warsaw	35.04	78.08	157	7.6	5
	Weldon	36.26	77.36	81	9.1	2
	Whitakers	36.06	77.43	109	10.0	3
	Whiteville	34.19	78.43	61	7.6	4
	Williamston	35.51	77.02	10	8.4	8
	Wilmington	34.16	77.55	38	7.5	11
	Wilson	35.43	77.56	145	10.3	7
	Windsor	36.00	76.54	20	8.2	4
	Winnabow	34.14	78.05	39	7.4	2
	Woodville	36.08	77.10	50	7.7	1

Table 1. Average values of background gamma dose rate measurements using portable gamma scintillation counters—continued

State and city		Latitude	Longitude	Altitude	Average (μrad/hr)	Number of observations
N. H:	Concord	43.12	71.30	342	11.1	8
	Hampton Falls	42.50	70.50	50	9.6	4
	Hampton	42.53	70.47	50	10.0	4
	Henniker	43.08	71.50	375	10.1	4
	Keene	42.55	72.17	490	9.4	6
	North Branch	43.04	72.00	400	10.5	2
	Northwood	43.12	71.09	570	10.8	3
	Portsmouth	43.04	70.47	40	10.4	21
	Rochester	43.18	71.00	400	10.5	3
	Seabrook	42.48	70.53	50	9.7	4
	Smithtown	42.46	70.51	50	10.0	4
N. J:	Absecon	39.28	74.30	13	6.8	2
	Adams Station	40.17	74.42	50	10.0	2
	Atlantic City	39.27	74.26	11	7.4	3
	Bayville	39.54	74.10	5	7.6	2
	Bayonne	40.40	74.05	115	9.1	2
	Bricktown	40.03	74.02	10	7.2	3
	Barnegate	39.44	74.17	8	6.9	3
	Burleigh	39.04	74.52	10	7.7	2
	Cape May	39.08	74.50	10	7.1	6
	Cape May courthouse	39.08	74.50	10	7.4	4
	Cedar Run	39.39	74.19	8	6.5	1
	Clarksville	40.15	74.45	5	8.3	3
	Clermont	39.07	74.50	10	6.7	1
	Cowtown	39.40	75.20	50	7.8	3
	Delmont	39.13	74.50	35	6.9	4
	Dennisville	39.12	74.40	30	7.6	2
	Eastontown	40.20	74.05	10	7.0	3
	Elizabeth	40.40	74.14	40	9.6	5
	Elmer	39.36	75.10	90	7.6	5
	Forked River	39.50	74.13	10	6.8	4
	Goshen	39.10	74.52	15	7.2	2
	Jersey City	40.44	74.03	135	9.3	4
	Key Port	40.23	74.15	40	7.8	4
	Linden	40.38	74.15	30	9.5	3
	Linwood	39.26	74.34	10	7.2	2
	Malaga	39.35	75.04	60	6.5	3
	Manahawkin	39.40	74.18	8	7.2	2
	Marmora	39.17	74.40	10	6.6	3
	Middletown	40.20	74.08	30	7.9	3
	Millville	39.24	75.03	60	6.6	7
	Neptune	40.12	74.01	10	8.5	5
	New Bedford	40.07	74.02	10	8.0	3
	New Brunswick	40.28	74.26	86	10.8	6
	New Gretna	39.34	74.28	18	6.7	2
	Newark	40.42	74.10	11	9.3	5
	Northfield	39.27	74.33	12	7.1	3
	Oceanview	39.08	74.44	10	7.0	4
	Oceanville	39.29	74.28	15	7.1	3
	Oceanport	40.22	74.03	10	7.2	1
	Palermo	39.15	74.42	10	6.5	1
	Parkertown	39.37	74.20	16	6.6	1
	Penns Neck	40.16	74.44	52	9.5	3
	Perth Amboy	40.30	74.19	80	10.0	1
	Pine Beach	39.55	74.11	8	7.0	1
	Pleansantville	39.22	74.32	10	6.9	4
	Point Pleasant	40.05	74.02	10	7.0	5
	Port Elizabeth	39.20	74.55	40	6.4	2
	Rahway	40.36	74.16	20	10.1	2
	Red Bank	40.25	74.06	18	8.2	3
	Rio Grande	39.01	74.54	10	7.7	3
	South Dennis	39.12	74.51	15	7.0	2
	Sayreville	40.25	74.25	60	8.3	1
	Seaville	39.13	74.43	10	6.7	2
	Smithville	39.29	74.28	16	7.1	2
	Somers Point	39.20	74.34	10	7.0	2
	Staffordville	39.38	74.15	10	6.5	4
	Toms River	39.57	74.13	10	7.5	2
	Trenton	40.13	74.46	56	9.5	4
	Tuckertown	39.36	74.20	20	6.5	3
	Union City	40.42	74.08	120	10.7	2
	Vineland	39.28	75.03	60	6.7	3
	Wanamasser	40.13	74.01	10	7.6	3
	Waretown	39.45	74.15	8	7.0	3
	Whitesboro	39.02	74.53	10	7.1	2
	Woodbridge	40.35	74.20	100	8.2	1
	Woodstown	39.39	75.19	50	9.0	5
N. Y:	Auburn	42.54	76.32	715	9.4	7
	Avon	42.55	77.45	545	8.5	2
	Bellport Station	40.45	72.50	50	8.1	4
	Bethany	42.56	77.47	580	9.1	2
	Bronx	40.51	73.55	180	9.5	11
	Brooklyn	40.36	73.59	15	9.5	9
	Cazenovia	42.55	75.45	1000	8.9	4
	Commack	40.45	73.27	120	8.4	4

Table 1. Average values of background gamma dose rate measurements using portable gamma scintillation counters—continued

State and city		Latitude	Longitude	Altitude	Average (μrad/hr)	Number of observations
N. Y:	Centereach	40.59	73.04	50	8.4	3
	Darian	42.57	77.50	600	9.8	2
	Depew	42.58	70.35	700	9.8	2
	Duanesburg	42.45	74.15	500	9.6	4
	East Quogue	40.51	72.00	80	8.1	3
	Eastport	40.46	72.40	60	7.5	3
	Fredonia	42.25	79.18	760	9.7	4
	Geneva	42.53	77.00	590	9.2	4
	Hampton Bay	40.58	71.45	100	8.0	4
	Huntington	40.45	73.30	120	8.9	5
	Jericho	40.51	73.25	100	8.3	7
	La Fayette	42.54	76.08	500	9.2	2
	Lancaster	42.58	78.33	705	9.1	2
	Madison	42.55	75.30	900	9.0	4
	Manhattan	40.47	74.58	132	8.7	12
	Middle Isle	40.59	72.58	50	7.9	2
	Oyster Bay	40.50	73.35	100	8.9	2
	Patchoque	40.45	73.03	30	7.7	4
	Portland	42.20	79.29	800	9.3	2
	Potter Hill	42.50	73.43	250	11.0	3
	Queens	40.39	73.47	13	9.1	5
	Richfield	42.45	75.03	875	9.3	4
	Ridge	40.59	72.55	50	7.4	1
	Ripley	42.03	79.50	985	9.5	4
	Riverhead	40.58	72.43	100	7.6	4
	South Buffalo	42.53	78.45	700	10.9	1
	Schnectady	42.50	73.55	225	8.9	9
	Seldon	40.59	73.01	50	7.7	3
	Seneca Falls	42.54	76.50	460	8.9	6
	Sharon	42.45	74.50	800	9.2	3
	Silver Creek	42.30	79.10	730	10.0	3
	Smithtown	40.46	73.20	100	8.5	3
	Staten Island	40.36	74.10	80	9.2	10
	Troy	42.50	73.45	24	10.3	9
	Wading River	40.59	72.48	50	9.3	3
	West Avon	42.55	77.45	545	8.5	1
	West Bloomfield	42.54	77.30	545	8.2	1
	West Canadaiqua	42.54	77.15	580	8.9	4
	West Hampton	40.45	72.15	70	8.6	3
	Westfield	42.17	79.37	975	9.5	2
Ohio:	Columbus	40.00	82.53	812	10.8	1
	Darlington	40.30	82.35	790	9.9	1
	Pleasant Home	40.50	82.10	740	9.9	1
	Willoughby	41.41	81.24	612	10.1	1
Pa:	Austinberg	42.00	77.32	1590	9.7	2
	Concordville	39.45	75.30	50	9.8	2
	Elam	39.42	75.32	60	9.9	2
	Erie	42.05	80.11	732	10.1	1
	Media	39.50	75.28	45	11.9	2
	Morrisville	40.15	74.48	50	9.4	2
	Oxford Valley	40.13	74.52	48	10.1	2
	Penndel	40.10	75.00	40	11.2	4
	Philadelphia	39.57	75.11	30	10.8	30
	Upper Darby	39.57	75.15	35	10.2	6
R. I:	Clayville	41.45	71.50	50	10.1	3
	Providence	41.44	71.26	51	9.6	42
	Rice City	41.41	71.53	50	9.7	3
	Vernon	41.43	71.52	50	11.1	3
S. C:	Allendale	33.00	81.20	200	8.4	8
	Ashepoo	32.40	80.30	9	8.5	3
	Awendaw	32.55	79.35	10	7.4	4
	Bamberg	33.17	81.03	165	8.1	6
	Bowman	33.18	80.42	100	7.7	5
	Byrds	33.10	80.33	100	7.6	1
	Charleston	32.47	79.54	9	10.0	14
	Coosahatch	32.30	80.53	53	7.9	3
	Dorchester	33.08	80.30	95	8.3	2
	Effingham	34.04	79.45	58	7.7	2
	Florence	34.13	79.46	144	8.0	7
	Gable	33.46	80.10	80	7.9	1
	Garden City Beach	33.41	78.55	10	9.1	2
	Gardens Corner	32.32	80.28	40	9.0	2
	Georgetown	33.22	79.17	14	7.2	11
	Hardeeville	32.15	80.58	40	8.6	7
	Jacksonboro	32.43	80.25	9	8.4	3
	Jedburg	33.05	80.25	90	8.9	1
	Litchfield	33.29	79.03	12	7.6	3
	Little River	33.53	78.40	15	7.1	3
	Manning	33.42	80.14	95	8.0	5
	Marion	34.11	79.24	68	8.1	5
	McClellanville	33.05	79.28	10	7.2	4
	Mount Pleasant	32.45	79.50	10	8.1	5
	Mullins	34.13	79.18	50	7.7	4

Table 1. Average values of background gamma dose rate measurements using portable gamma scintillation counters—continued

State and city		Latitude	Longitude	Altitude	Average (μrad/hr)	Number of observations
S. C:	Murrells Inlet	33.30	79.01	10	6.8	3
	Myrtle Beach	33.43	78.48	15	7.6	5
	Nichols	34.15	79.10	40	6.8	3
	Ocean Drive Beach	33.51	78.42	15	6.6	4
	Olanta	33.53	79.55	60	7.8	4
	Pee Dee	34.12	79.32	60	8.0	2
	Pawleys Island	33.25	79.08	12	7.0	3
	Orangeburg	33.30	80.52	244	9.1	6
	Pocataligo	32.32	80.48	50	8.9	2
	Pregnall	33.09	80.32	100	8.1	1
	Rantowles	32.45	80.15	9	8.9	4
	Ridgeland	32.28	80.58	57	8.1	4
	Ridgeville	33.14	80.45	90	10.5	3
	Rosinville	33.12	80.40	105	7.6	2
	Santee	33.13	80.42	100	8.7	7
	Sardinia	33.48	80.02	80	8.2	2
	Sheldon	32.31	80.45	45	8.7	2
	South Carolina line	32.56	81.02	200	8.2	1
	St. George	33.11	80.34	109	9.3	4
	Summerton	33.35	80.18	90	8.4	4
	Summerville	33.02	80.12	75	7.8	3
	Surfside	33.40	78.50	10	8.0	4
	Turbeville	33.50	80.01	70	6.3	3
	Ulmers	33.10	81.15	200	8.1	6
	Windy Hill	33.45	78.45	15	7.3	4
Tenn:	Chattanooga	35.02	85.12	665	9.8	7
	Dayton	35.30	85.01	810	9.0	3
	East Ridge	35.01	85.20	650	9.3	2
	Elgin	36.20	84.39	1475	9.6	1
	Evansville	35.40	84.58	850	8.9	1
	Georgia and Tennessee line	35.00	85.25	650	9.1	1
	Glenmary	36.18	84.41	0	9.9	1
	Graysville	35.25	85.05	750	10.6	1
	Harrimans	35.58	84.35	935	9.3	1
	Isham	36.35	84.27	1400	9.2	1
	Lancing	36.09	84.41	1480	8.9	1
	New River	36.25	84.37	1450	10.3	2
	Oneida	36.30	84.31	1450	9.5	2
	Robbins	36.24	84.39	1460	10.6	2
	Rockwood	35.52	84.41	930	9.3	3
	Sale Creek	35.20	85.06	700	9.1	1
	Spring City	35.47	84.55	900	8.5	1
	Sunbright	36.14	84.42	1495	9.9	1
	Wartburg	36.08	84.40	1450	10.0	1
	Winfield	36.34	84.27	1425	8.8	1
Vt:	Bennington	42.55	73.13	670	9.5	7
	Brattleboro	42.45	72.35	300	8.6	4
	Wilmington	42.55	73.13	400	9.2	4
Va:	Accomac	37.45	75.38	20	8.3	4
	Alexandria	38.48	77.05	70	9.1	6
	Arlington	38.50	77.05	70	9.0	10
	Capron	36.44	76.30	35	7.9	2
	Carmel Church	37.40	77.21	90	8.7	2
	Charles City	37.22	77.05	100	8.9	4
	Chesepeake	36.25	76.20	10	8.0	3
	Cheriton	37.17	75.58	11	7.0	1
	Dreweryville	36.42	76.31	50	8.4	2
	Dumfries	38.32	77.20	100	10.2	2
	Eastville	37.20	75.55	15	6.9	1
	Engleside	38.43	77.13	220	8.9	2
	Emporia	36.41	77.33	80	10.0	8
	Exmore	37.33	75.50	32	7.9	3
	Fredricksburg	38.18	77.28	20	9.3	6
	Golansville	37.45	77.23	85	7.8	2
	Groveton	38.46	77.06	245	8.9	2
	Gum Tree	37.35	77.21	100	8.9	4
	Hampton	37.03	76.23	20	8.5	7
	Kiptopeke Beach	37.13	76.00	10	8.0	2
	Ladysmith	37.50	77.24	80	7.8	3
	Machipongo	37.25	75.53	25	7.3	1
	Massaponax	38.00	77.26	55	8.6	3
	Nassawa Dox	37.28	75.52	35	7.8	2
	Nelsonia	37.48	75.35	18	8.8	2
	New Church	37.56	75.22	10	8.6	3
	Newport News	36.59	76.26	25	8.9	8
	Norfolk	36.56	76.00	26	7.9	9
	Oak Hill	37.55	75.25	14	8.7	2
	Onley	37.43	75.40	25	7.9	2
	Painter	37.35	75.49	30	8.1	2
	Pohick	38.42	77.16	210	9.2	1
	Richmond	37.30	77.20	162	9.2	14
	Skippers	36.38	77.33	80	9.7	2
	Stafford	38.20	77.23	15	8.7	4
	State Park	36.52	76.06	20	8.0	3

Table 1. Average values of background gamma dose rate measurements using portable gamma scintillation counters—continued

State and city		Latitude	Longitude	Altitude	Average (arad/hr)	Number of observations
Va:	Tasley	37.44	75.39	22	7.6	1
	Temperance	37.53	75.30	16	8.4	2
	Thornburg	37.55	77.25	70	8.9	3
	Triangle	38.30	77.21	12	9.3	1
	Virginia & North Carolina Line	36.36	77.33	80	8.8	1
	Virginia Beach	36.51	76.00	16	7.6	3
	Williamsburg	37.18	76.42	70	8.1	6

Iodine-131 in Bovine Thyroids, April-June 1968

National Center for Radiological Health
Public Health Service

The National Center for Radiological Health established a Bovine Thyroid Network in October 1964 (*1*). Specimens are collected by the Livestock Slaughter Inspection Division, U.S. Department of Agriculture, and are analyzed by gamma-ray spectroscopy for iodine–131 content at the Northwestern Radiological Health Laboratory, Winchester, Mass.

The network consists of collection areas (countries shaded in figure 1) located so as to cover, as nearly as possible, areas near major nuclear reactors, spent fuel reprocessing plants and nuclear test sites. Details of sampling and analyses have been published earlier (*1*).

The results for April through June 1968 appear in table 1 and are listed chronologically within each State. The iodine–131 levels in thyroids of all samples collected during this period were not above the barely detectable level of 2 to 5 pCi iodine–131/g thyroid except for one sample collected May 10, 1968, in Walla Walla, Wash. (7pCi iodine–131 g thyroid).

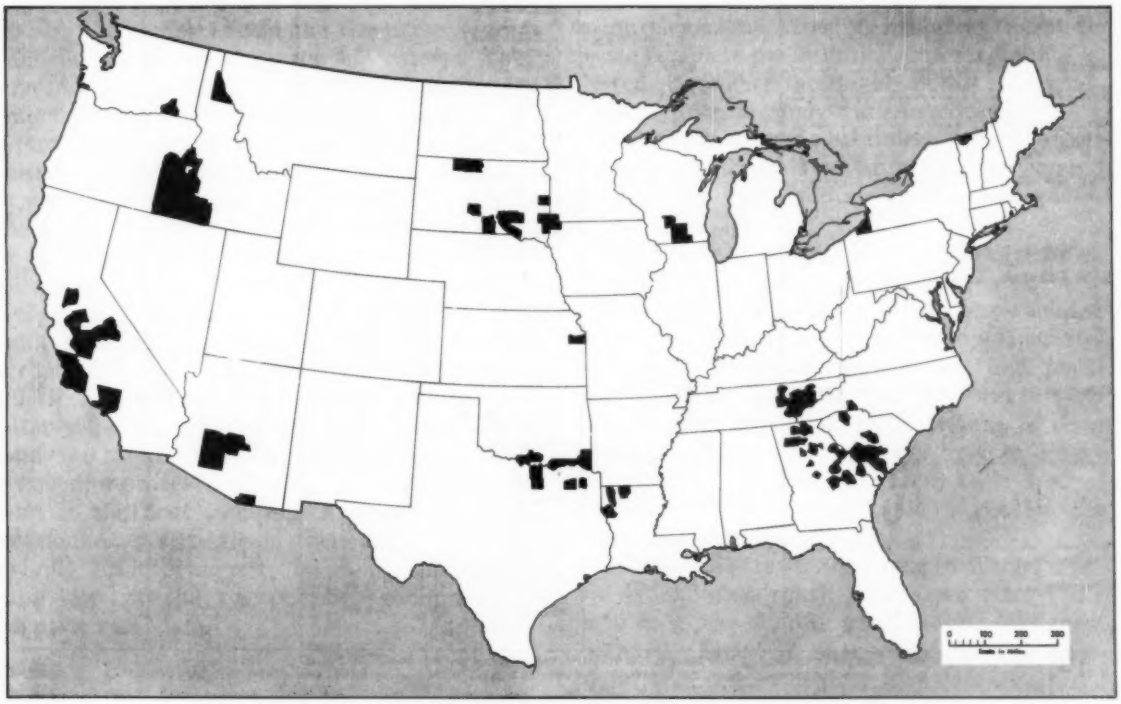

Figure 1. Counties sampled in Bovine Thyroid Network, April–June 1968

REFERENCE

(1) BARATTA, E. J., E. R. WILLIAMS, and G. MURRAY. Iodine–131 in bovine thyroids, October–December 1964. Radiol Health Data 6:569–571 (October 1965).

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
October–December 1967	May 1968
January–March 1968	August 1968

Table 1. Iodine–131 in bovine thyroids, April–June 1968

State	Dates of slaughter	County	Number of samples	Average concentration
				pCi iodine-131/g thyroid
Arizona	4/3	Maricopa	1	ND
	4/11		1	2
	[a] 4/17–6/27		12	ND
	5/1	Pinal	1	ND
California	[a] 4/20–6/26	Merced (1) [c] Monterey (7) San Benito (15) San L. Obisco (3) Santa Clara (3)	29	ND
Georgia	[a] 4/9 –6/26	Bartow (5) [c] Bibb(8) Burke (3) Butts (2) Candler (4) Clarke (6) Dodge (2) Evans (2) Forsyth (8) Fulton (5) Greene (4) Jenkins (6) Laurens (2) McDuffie (6) Richmond (1) Screven (9) Thomas (2) Upson (2) Warren (6) Wilkes (13)	96	[b] ND
Idaho	4/8	Canyon	5	ND
Iowa	4/1	Lyon	8	ND
	5/9	Lyon	7	ND
Kansas	4/23–4/24	Douglas	2	ND
Louisiana	[a] 5/3 –6/20	Claiborne (1) [c] Natchitaches (2) Red River (1)	4	ND
Minnesota	5/21	Rock	4	ND
	6/12	Lincoln	1	ND
Mississippi	[a] 6/17–6/25	Forrest (1) [c] Hinds (1) Jackson (1) Jones (2) Lauderdale (7) Marion (1)	13	ND
Nebraska	6/10	Platte (2) [c] Sanders (1)	3	ND
New York	[a] 4/3 –6/18	Cattaraugus (10) [c] Chautaugua (40)	50	ND
North Carolina	4/2	Cleveland	4	ND
Oklahoma	[a] 4/2 –6/19	Bryan (1) [c] Carter (7) Choctaw (1)	9	ND
South Carolina	[a] 4/2 –6/26	Bamberg (5) [c] Barnwell (4) Edgefield (1) Greenwood (4) McCormick (2) Orangeburg (3) Saluda (2)	21	[b] ND
South Dakota	[a] 4/1 –6/26	Aurora (10) [c] Brookings (7) Brule (1) Clark (11) Faulk (3) Grant (2) Gregory (1) Hanson (3) Hamlin (1) Kingsbury (7) Lake (3) Minnehaha (6) Roberts (8) Tripp (7) Turner (1)	71	[b] ND
Tennessee	[a] 4/3 –6/25	Blount (1) 0[c] Knox (5) Loudon (2) Sevier (2) Union (1)	20	[b] ND
Texas	[a] 4/1 –6/24	Bowie (1) [c] Cass (2) Cooke (1) Denton (6) Hopkins (2) Titus (2)	14	ND
Vermont	[a] 4/24–6/18	Franklin	52	ND
Washington	[a] 5/6 –6/28	Walla Walla	23	ND
	5/10	Walla Walla	1	7
Wisconsin	[a] 4/12–6/28	Dane (30) [c] Green (1) Portage (6) Rock (13)	50	ND

[a] Samples were not collected on all dates during this period, but the interval includes several sampling dates.

[b] The results for this period were for the most part, not detectable. Some randomly scattered positive results were obtained; but these represented barely detectable amounts of iodine-131 in the bovine thyroid (2 to 5 pCi/g).

[c] Numbers in parentheses represent the number of samples collected from that county during the interval indicated. These may have been collected over several dates during the period or on only one date.

Radionuclides in Washington Shellfish[1], January 1963-December 1967

Washington State Department of Health

As part of their surveillance of radioactivity in the environment, the Washington State Department of Health routinely collects oysters and clams for analysis. These shellfish have the ability to concentrate radionuclides such as phosphorus–32 and zinc–65, attaining levels far above the ambient concentrations present in the water.

Samples from the Washington coast and the Olympia and Dabob Bay areas of Puget Sound are collected by the Food Protection Section of the Washington State Health Department. Those from the Bangor Naval Ammunition Depot are collected by the U.S. Navy and sent to the State Health Department through the Kitsap-Bremerton Health District, which also collects the samples from the Bremerton area.

Shells are removed in the laboratory. The supernatant liquid is decanted and the entire edible portion is homogenized and placed in a 1-pint cottage cheese container for analysis on the multichannel analyzer. Four hundred grams of sample are analyzed when available. After the gamma analysis, phosphorus–32 separation is performed by a modification of techniques described in the literature (*1–4*). Twenty-five grams of the homogenized sample are completely ashed using dry and wet ashing techniques. The total ash is treated with hydrofluoric acid to dissolve any silicates present, and after complete removal of excess hydrofluoric acid, the sample is dissolved in 3N nitric acid. Ammonium nitrate is added to give 5–10 percent in the final solution. A large excess of ammonium molybdate is then added and the sample left overnight to insure complete precipitation of the phosphorus as ammonium phosphomolybdate.

Interfering ions are also precipated and must be removed. The precipitate is washed with a 5 percent solution of ammonium nitrate, then dissolved in 6N ammonium hydroxide containing 0.5 g citric acid. The citric acid will complex most interfering ions. To this solution, magnesia mixture (containing magnesium chloride and ammonium chloride) is added to precipitate the phosphorus as magnesium ammonium phosphate. After standing overnight, the alkaline filtrate is discarded and the precipitate washed thoroughly with 1:20 ammonium hydroxide. It is then dissolved in warm, very dilute hydrochloric acid. The magnesia precipitation is repeated, but from an acid solution to insure complete and final separation from interfering elements. After standing overnight to insure complete precipitation, the precipitate is filtered off, washed thoroughly with 1:20 ammonium hydroxide and transferred, using 3N nitric acid, to a weighed stainless steel planchet. After drying in an oven at 110°C, the sample is submitted for counting of the beta radioactivity.

Table 1 lists results of all oyster samples arranged according to collection area and collection date. Quantitative results extrapolated to date of collection for ruthenium–106, zirconium–95, zinc–65, potassium–40, and phosphorus–32 are included for the period July 1964 through December 1967. Results of clam samples (which were collected only in Puget Sound) have been omitted from table 1 since all data other than potassium–40 was below the respective detectability limits.

To illustrate trends occurring in oysters from the Washington coast, data from past years have been presented in graphic form in figures 1 and 2. Figure 1 shows zinc–65 and phosphorus–32 concentrations in oysters collected from Stony Point in Willapa Bay during the

[1] Summarized from the annual and quarterly reports of the Washington State Department of Health.

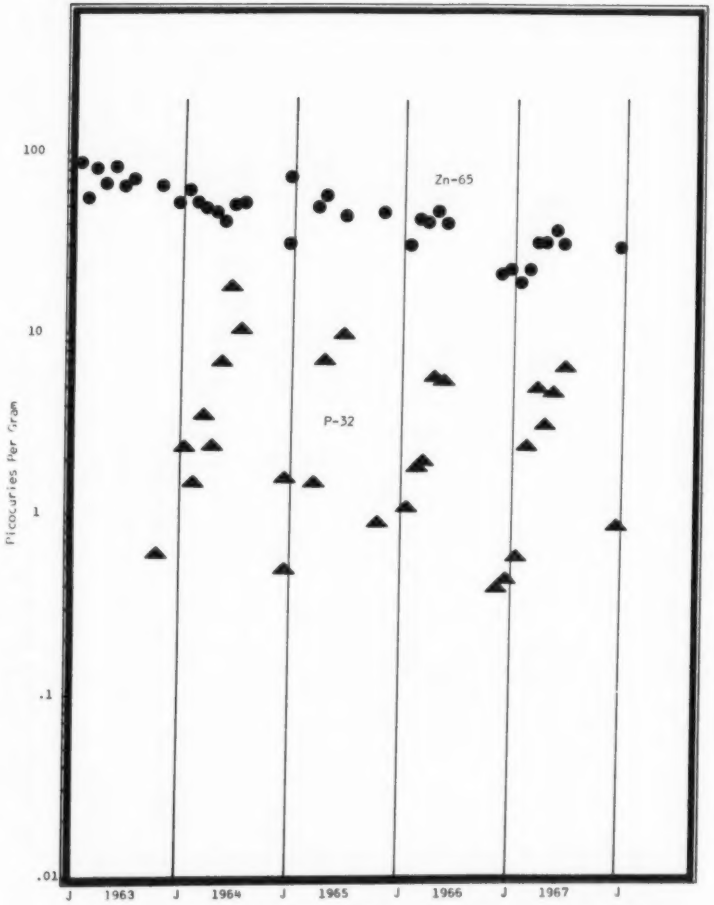

Figure 1. ^{65}Zn and ^{32}P in Willapa Bay oysters, Stony Point

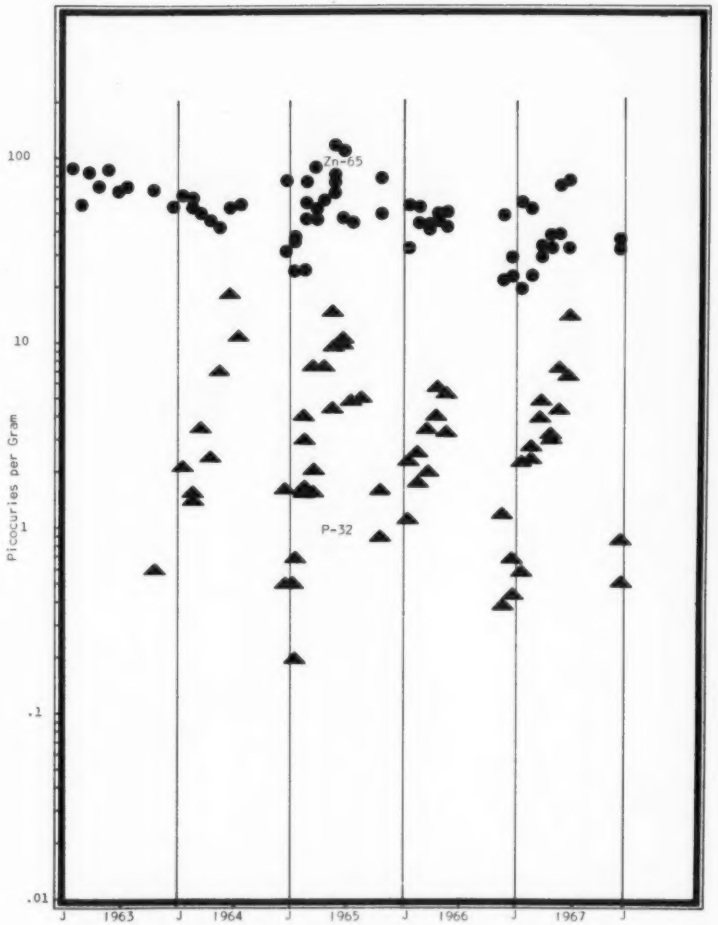

Figure 2. ^{65}Zn and ^{32}P in Willapa Bay oysters, all stations

Table 1. Oyster analyses, July 1964 through December 1967

Collection date	Location	Year [a]	Concentration (pCi/g wet weight) [b]				
			Phosphorus-32	Potassium-40	Zinc-65	Zirconium-95	Ruthenium-106 [c]
	PUGET SOUND						
1964							
July 30	Oyster Bay	1961	<0.03	2.0	0.2	<0.03	<0.3
1965							
April 22	Oyster Bay	1962	<.03	1.7	.3	<.03	<.3
1966							
January 15	Dabob Bay	1960–61	<.03	1.6	1.1	<.04	<.3
February 28	Dabob Bay	1960–61	<.03	2.2	1.1	<.04	<.3
March 17	Bangor	Natural Set.	<.03	1.8	1.0	<.04	<.3
April 9	Dabob Bay	Unknown	<.03	1.9	1.0	<.04	<.3
April 19	Bangor	Natural Set.	<.03	2.3	1.0	<.11	<.8
April 19	Dungeness	Unknown	<.03	2.3	2.3	<.04	<.3
April 27	Olympia	Unknown	<.03	2.0	.2	<.04	<.3
May 18	Bangor	Natural Set.	<.03	2.4	1.2	.05	.4
June 16	Bangor	Natural Set.	<.03	2.3	1.0	<.07	<.6
July 20	Bangor	Unknown	<.03	1.9	.7	<.08	<.6
August 29	Bangor	Unknown	<.03	2.2	.7	<.08	<.6
September 29	Bangor	Unknown	<.03	2.2	.6	<.06	<.5
1967							
January 3	Olympia	1958	<.03	2.1	.2	NA	NA
January 15	Olympia	1958	<.03	2.0	.1	<.020	<.25
February 22	Bangor	Natural	<.03	1.6	.8	<.050	<.63
March 15	Bangor	Natural	<.03	1.8	.7	<.026	<.33
April 27	Bangor	Natural	<.03	2.0	.6	<.034	<.43
May 24	Bangor	Natural	<.03	1.3	.6	<.026	<.33
June 21	Bangor	Natural	<.03	2.0	.7	<.034	<.42
April 18	Dabob Bay	Natural	<.03	2.1	.5	<.032	<.40
April 27	Olympia	1958	<.03	2.2	.1	<.020	<.25
August 17	Bangor	Natural	<.03	2.7	.67	<.050	<.63
July 20	Bangor	Natural	<.03	1.7	.57	<.032	<.40
December 18	Lt. Skookum Bay	1963	<.03	2.3	.23	<.020	<.25
	GRAYS HARBOR						
1964							
July 28	Ocosta	Unknown	10.0	2.1	46	<.03	.4
December 3	Ocosta	Unknown	.2	1.7	16	<.03	<.3
1965							
January 13	Ocosta	1962	.4	1.7	37	<.03	.4
February 25	Ocosta	1962	1.3	1.2	35	<.03	<.3
July 29	Ocosta	Unknown	.6	2.4	10	<.04	<.3
October 28	Ocosta	Unknown	.6	2.1	19	<.05	<.4
November 18	Grass Creek	1963	.9	1.6	27	<.04	<.3
1966							
January 18	Ocosta	Unknown	1.4	1.5	26	.04	<.3
February 7	Ocosta	Unknown	.9	2.0	22	<.04	<.3
April 10	Ocosta	Unknown	2.3	2.0	29	<.04	<.3
November 15	Ocosta	Unknown	.20	2.6	16	<.04	<.30
December 16	Ocosta	1962	.48	2.0	14	<.04	<.30
1967							
January 16	Ocosta	Unknown	.52	1.3	16	<.020	.37
February 25	Ocosta	Unknown	.60	1.2	15	.061	.25
March 23	Ocosta	1964	3.39	1.5	28	.022	.25
April 17	Ocosta	1964–65	2.07	1.8	29	<.020	<.25
May 12	Ocosta	1964	2.77	2.1	35	<.020	<.25
June 27	Ocosta	1964	3.87	1.9	30	.053	1.03
December 11	Manard	Unknown	.50	1.6	18	<.020	<.25
	WILLAPA BAY						
1964							
July 28	Stony Point	Unknown	10.6	1.7	54	.06	1.0
December 4	Stony Point	1961	1.6	1.8	75	.07	.4
December 4	Stony Point	1963	.5	1.7	31	<.03	<.3
1965							
January 14	No. River Fl.	1958	.2	1.5	24	<.03	<.3
January 14	No. River Fl.	1962	.7	1.4	36	.04	<.3
January 14	Bay Center	1962	.5	1.5	34	.04	<.3
February 25	Oysterville	1961	3.0	1.7	55	<.03	.4
February 25	No. River Fl.	1962	1.5	1.6	24	<.03	<.3
February 25	Stackpole	1961	4.2	2.2	72	<.03	<.3
February 25	Oysterville	1961	1.6	1.9	45	<.03	.6
March 23	Stackpole	1961	7.3	2.3	85	.10	<.3
March 23	Stony Point	1962	1.5	1.9	51	.06	<.3
March 23	Bay Center	1961	2.1	1.6	45	.03	.4
April 21	Stony Point	1962	7.2	1.8	58	.04	<.3
May 18	Bay Center	1959	9.7	2.0	72	.05	.5
May 18	Long Island	Unknown	4.3	2.5	63	<.03	.8
May 18	Nemah Flats	1962	14.7	2.2	78	<.03	<.3
May 18	Stackpole	Natural	14.9	1.9	114	.04	<.3

See footnotes at end of table.

Table 1. Oyster analyses, July 1964 through December 1967—Continued

Collection date	Location	Year [a]	Concentration (pCi/g wet weight) [b]				
			Phosphorus-32	Potassium-40	Zinc-65	Zirconium-95	Ruthenium-106 [c]
	WILLAPA BAY						
1965							
June 16	Stackpole	1962	10.4	2.3	106	<.04	.8
June 16	Stony Point	1961	9.7	1.8	46	<.04	.9
July 27	Oysterville	1962	4.9	2.5	43	<.04	<.3
August 24	Stackpole	1962	5.1	NA	NA	NA	NA
October 10	Stackpole	Unknown	1.6	2.2	76	<.04	<.3
October 28	Stony Point	1962	.9	1.9	49	.05	<.3
1966							
January 18	Stackpole	Unknown	2.3	2.0	53	<.04	<.3
January 18	Stony Point	Unknown	1.1	1.8	31	.05	<.3
February 8	Stony Point	1962–63	1.8	2.4	43	<.04	<.3
February 9	Oysterville	Unknown	2.6	2.0	53	<.04	<.3
March 30	Oysterville	1963	3.4	1.8	40	.04	<.3
March 30	Stony Point	1962	2.0	2.1	42	.05	<.3
April 11	Oysterville	Unknown	4.1	2.2	44	.09	<.3
April 10	Stony Point	Unknown	5.6	1.8	48	.08	<.3
May 18	Stony Point	1963	5.4	2.0	41	<.04	<.3
May 19	Oysterville	Unknown	3.3	2.3	50	<.04	<.3
November 15	Stony Point	1964	.40	1.6	21	<.02	<.30
November 16	Stackpole	Unknown	1.23	1.8	48	<.02	<.30
December 15	Stackpole	1962–63	.70	1.6	29	.026	<.30
December 19	Stony Point	1964	.45	1.7	22	<.02	<.30
1967							
January 18	Stackpole	1960–64	2.30	1.7	57	.031	.75
January 18	Stony Point	1964	.58	1.8	19	<.020	.53
February 25	Stackpole	1963–65	2.82	2.3	51	<.020	.46
February 26	Stony Point	1963–64	2.41	1.5	23	<.020	.28
March 28	Stony Point	1965	4.94	1.6	32	<.020	.28
March 28	Oysterville	1964	4.03	1.7	29	.026	.32
April 18	Stackpole	1963–64	2.99	1.9	38	<.020	<.25
May 16	Stackpole	1963–64	7.34	2.1	70	.033	<.25
June 27	Stackpole	1964	14.26	2.3	74	.026	<.25
April 19	Stony Point	1965	3.12	1.5	32	<.020	.43
May 17	Stony Point	1964	4.45	1.8	39	.027	.77
June 27	Stony Point	1964	6.48	1.9	32	<.020	.27
December 11	Oysterville	1962	.52	1.9	35.87	<.020	<.25
December 11	Stony Point	Unknown	.86	1.7	30.46	<.020	<.25

[a] Planting year of oyster seed in growing beds.
[b] All results extrapolated to date of collection.
[c] Net radioactivity in the 0.44–.56 MeV gamma range, computed as ruthenium-106.
NA, no analysis performed.

period January 1963 through December 1967. Various factors inherent in the data preclude defining specific trends. The total number of samples is small, and a three-fold variation has been found between oysters taken from the same growing beds. A complete history of each sample is often unknown, and the residency time in a specific growing bed has varied from a few months to more than 3 years. Some oysters are seeded in Puget Sound, later moved to Willapa Bay, and then moved once again before harvesting.

Figure 2 is a graph of zinc–65 and phosphorus–32 concentrations for all oyster samples collected in Willapa Bay. In addition to the variables discussed above there are apparent differences in isotope concentrations due to location of the growing beds within the bay. These variables influence interpretation of trends in the data, but figures 1 and 2 still show an increase in phosphorus–32 levels each spring with a corresponding decrease in the fall and winter. This would result from ocean currents carrying the Columbia River effluent southward in the summer and northward in the winter. The short half-life of phosphorus–32 causes varying concentrations with exposure while there would be little change seen in the longer half-life zinc–65.

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Environmental Levels at Radioactivity at Atomic Energy Commission Installations

The U.S. Atomic Energy Commission receives from its contractors semiannual reports on the environmental levels of radioactivity in the vicinity of major AEC installations. The reports include data from routine monitoring programs where operations are of such a nature that plant environmental surveys are required.

Releases of radioactive materials from AEC installations are governed by radiation standards set forth by AEC's Division of Operational Safety in directives published in the AEC Manual.[1]

Summaries of data from the environmental radioactivity monitoring reports follow for the Los Alamos Scientific Laboratory and Rocky Flats Plant.

[1] Title 10, Code of Federal Regulations, Part 20, "Standards for Protection Against Radiation," contains essentially the standards published in Chapter 0524 of the AEC Manual.

1. Los Alamos Scientific Laboratory [2] Calendar year 1967

University of California
Los Alamos, New Mexico

As part of the environmental monitoring program at Los Alamos, measurements of beta radioactivity in airborne particulates and precipitation, are made periodically. The samples have been taken on the roof of building TA–50 (about 1¾ miles southeast of the Administrative Building) since March 1963.

Air monitoring

Airborne radioactive particulate matter is collected on 4-inch-diameter filters. The sampling rate was reduced from 46 m^3/hr in 1962 to 25.5 m^3/hr in 1963, due to the addition of an activated charcoal filter behind the first filter. Air samples are ordinarily collected for 24-hour intervals during the work week, and weekend samples are collected for a 72-hour period.

The filters are counted for beta radioactivity 7 days after collection in a thin-window (methane) flow proportional counter with an overall efficiency for strontium-yttrium–90 of 50 percent.

In September 1966, a large chamber was added to the "Sharp Widebeta Counting System" that permits the counting of these air samples in the same geometry as the precipitation samples. The efficiency for strontium-yttrium–90 remains the same as in the older counter.

Precipitation monitoring

Collection is made in a 0.4 square meter rain collector which delivers 1 liter of water for each 0.1 inch of precipitation. It has been found that this arrangement collects radioactivity even during relatively dry periods. By washing down the sides of the collector with 1 liter of distilled water, a suitable sample is obtained.

[2] Summarized from "Beta Radioactivity in Environmental Air and Precipitation at Los Alamos, New Mexico, for 1967" (LA–3887).

These "wash" samples, as well as any precipitation, are reduced in volume, dry-plated on 1-inch stainless steel planchets, and counted in an automatic beta-particle counting system. This system has a gas-flow proportional counter, which provides increased efficiencies and lower background than previous systems.

Results

Average daily radioactivity concentrations for air collected are weighted for sample periods of more than 1 day. Average radioactivity concentrations for the precipitation collection are calculated from the total radioactivity collected during the month divided by the number of days in the month. Summary of the daily air data (pCi/m^3) shows the maximum was 2.67, minimum less than 0.01; and the average 0.037. The precipitation data (nCi/m^3) shows the maximum was 32.7; minimum 0.003; and the average 0.16.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
Calendar year 1966	December 1967

2. Rocky Flats Plant [3] January–June 1968

Dow Chemical Company
Golden, Colorado

The Rocky Flats Plant (RFP) is engaged in routine production operations involving plutonium and uranium under contract to the Atomic Energy Commission. Its location, relative to population centers, is shown in figure 1. To assure properly controlled release of radioactive materials to the environment, periodic samples of air, water, and vegetation are analyzed for gross alpha radioactivity. The most abundant radioactive material involved in the process is plutonium.

The plant is located about 15 miles northwest of Denver. The surface stratum in this area consists of gravel washed out of the highly mineralized front range of the Rocky Mountains, where heterogeneous low-level deposits of uranium, thorium, and radium exist in the soil. These materials are measurable in most samples of air, water, and vegetation.

Air

Continuous air samples were collected at Coal Creek Canyon, Marshall, Boulder, Lafayette, Broomfield, Wagner School, Golden, Denver, and Westminster. The monthly average long-lived gross alpha radioactivity shown in table 1 are believed to result from naturally occurring materials. All values are less than

Table 1. Long-lived gross alpha radioactivity in airborne particulates, RFP environs, January–June 1968

Period (1968)	Average concentration (pCi/m^3)
January	0.3×10^{-4}
February	2.2×10^{-4}
March	0.5×10^{-4}
April	0.5×10^{-4}
May	0.3×10^{-4}
June	0.7×10^{-4}

[3] Summarized from "Environmental Survey, January–June 1968," The Dow Chemical Company, Rocky Flats Division, Golden, Colo.

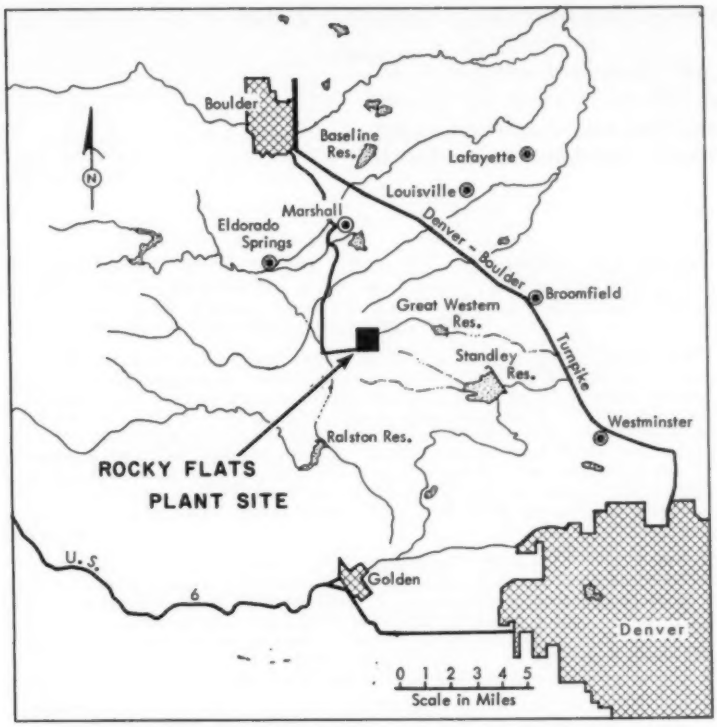

Figure 1. Rocky Flats Plant and environs near Denver, Colorado

the AEC standard of 0.04 pCi/m³ for mixtures of unidentified radionuclides.

Water

Regular water samples were obtained monthly except during the winter months from four reservoirs in the area of the Rocky Flats Plant. The results of alpha radioactivity analyses performed on these samples are given in table 2. The analytical results for water samples obtained during the summer collection period from outlying streams and lakes during the July collection period will be tabulated in the next report. For comparison purposes, the AEC standard for mixtures of unidentified radionuclides in water is 10 pCi/liter.

Table 2. Alpha radioactivity in water, RFP environs January–June 1968

Reservoir	Number of samples	Average concentration (pCi/liter)
Great Western	4	2.3
Standley	4	1.3
Baseline	5	1.2
Ralston	5	4.2

Vegetation

During this period, January–June 1968, no vegetation samples were collected. Additional samples collected in October 1967 and not previously reported are presented in table 3.

Table 3. Alpha radioactivity in vegetation RFP environs, October 1967

Collection period (1967)	Distance from plant	Number of samples	Average concentration (pCi/kg dry weight)
October 1967	Less than 3 miles	21	120
October 1967	3 to 18 miles	40	118

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
January–June 1967	January 1968
July–December 1967	May 1968

Reported Nuclear Detonations, October 1968

The U.S. Atomic Energy Commission announced a nuclear test of low yield (20 kilotons or less TNT equivalent) was conducted underground at its Nevada Test Site on October 3, 1968.

SYNOPSES

Synopses of reports, incorporating a list of key words, are furnished below in reference card format for the convenience of readers who may wish to clip them for their files.

WHOLE BODY CESIUM–137 AND ITS RELATION TO BODY COMPOSITION AND DIET. *R. C. Steinkamp, T. W. Sargent, E. Isaacs, N. L. Cohen, E. M. Hutson, and N. D. Kunkel. Radiological Health Data and Reports, Vol. 9, November 1968*, pp. 619–626.

Between September 1962 and July 1963, a time of rising cesium–137 content in the biosphere, whole body cesium–137 and potassium–40 measurements were performed in an Argonne-type scintillation counter on 80 subjects; 52 men and 28 women. These data have been correlated with body composition estimates of body fat and lean body mass. Seventy-eight of the subjects had diet interviews. The intakes of food categories were correlated with *in vivo* cesium–137 measurements. The results suggest that calculations of dose rates for cesium–137 may be more meaningful if based on lean body mass rather than total body weight, as is done presently.

Intakes of milk, fruits and vegetables correlated significantly with *in vivo* cesium–137 measurements for those subjects with extremely low or extremely high food intakes. A regression equation was determined to calculate pCi cesium–137/g potassium in people from pCi cesium–137/g potassium in milk. There appeared to be a time lag of 4 to 5 months between rising values of cesium–137 in milk and those in people, consistent with the biological half-life of cesium–137.

KEYWORDS: body burden, cesium–137, diet, dose rate, humans, milk, potassium–40.

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A list of suggested keywords (descriptors) which are appropriate indexing terms should be given following the abstract.

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